I. OVERVIEW

The Department of Energy (DOE) manages one of the largest and most distinguished laboratory systems in the world. With origins in the Manhattan Project, the DOE laboratories have evolved over the past 50 years to become a major component of the Nation's infrastructure for maintaining U.S. leadership in scientific discovery and knowledge generation. Programs conducted at the Department's laboratories have consistently challenged our basic understanding of the world around us and driven new fields of scientific inquiry and technology development.

Innovations and capabilities from the DOE laboratories are behind innumerable technological achievements that have affected the Nation's security, environmental quality, knowledge base, prosperity, and quality of life. Examples include:

- Development of the world's first nuclear explosive in a span of 28 months, from when the first scientists arrived at Los Alamos National Laboratory in 1942 to the first nuclear test in 1945.
- Development and continuous refinement of increasingly sophisticated computers. From the Univacs of the 1950s to the first trillion-operations-per-second supercomputers today, the Department's laboratories have been a test bed for the first model of nearly every new top-end computer.
- Technology breakthroughs in essentially all forms of energy sources and energy-efficiency technologies, including: the original work on nuclear reactors; development of enhanced methodologies for oil and gas exploration; creation of new battery technologies for electric vehicles, high-temperature superconducting materials, new substrates for photovoltaic panels, and new energy-efficient window and building technologies; and advances in the development of the scientific and technological foundations for fusion energy as a potential future energy source.[1]
- Original development of the field of medical isotope production and utilization and continued leadership in the field of nuclear medicine.

[1] See *Success Stories: The Energy Mission in the Marketplace*, May 1995, U.S. Department of Energy.

More than 60 Nobel Prize winners have been associated with the Department or its laboratories, including four of the five U.S. scientists who won Nobel Prizes in physics and chemistry in 1995.

In addition, the Department's laboratories have received more R&D 100 awards—the most widely recognized award for practical innovations—than has any other public or private organization.[2] In 1995, DOE's research was recognized with 32 of these awards.

The legacy of accomplishments by the Department's laboratories is clear, and their potential future contributions are great. Research currently under way at the DOE laboratories could help meet the national goals of:

- Environmental quality through clean energy sources and pollution-prevention technologies
- Enhanced security through technical advances that enable continued reductions in the nuclear risk without nuclear testing
- Sustained leadership across the frontiers of scientific knowledge
- Economic productivity through technology innovations that enter the marketplace through partnerships with the private sector

Although the Department of Energy laboratories had their origins in the Cold War, and their growth was fueled considerably by national security requirements, these institutions now serve a broad array of national needs. Optimizing their use to help meet the Nation's needs as we enter the 21st century will be a major challenge—and opportunity—of the post-Cold War world.

Reforms at the Department and its Laboratories

Tightening Federal budgets and shifting national priorities all have put new pressures on the Department of Energy and its laboratories. The Department has addressed these challenges through an ambitious set of reforms aimed at enhancing its strategic focus, cutting costs, and instituting management changes that improve performance.

With regard to the laboratories, the Department has pursued a series of initiatives over the past two years. Many of these were launched directly in response to recommendations of the Task Force on Alternative Futures for the

[2] Since the first of these awards in 1963, technologies funded by the Department of Energy have won more R&D 100 awards than all other government agencies combined and more than twice as many as the top industrial winner.

Department of Energy National Laboratories, which Secretary O'Leary established in February 1994 and which issued its report in February 1995.

The Department established the Laboratory Operations Board in April 1995 to ensure that dedicated management attention is provided on a continuing basis to issues involving the cost and performance of the Department's laboratories. The Board consists of an equal number of senior officials from the Department and external members drawn from the private sector, academia, and the public. The external members of the Board provide semiannual reports to the Secretary through the Secretary of Energy Advisory Board. In their first report, the external members provided the following overall assessment of reforms under way by the Department and its laboratories:

> We found that very substantial and pervasive changes presently are underway at the Department and the DOE laboratories. These changes hold the potential to substantially improve R&D productivity, enhance mission focus, and eliminate onerous administrative burdens at the DOE laboratories…The overall picture that we see includes reform actions that have been necessary for many years. Major administrative processes are being aggressively reengineered at several of the laboratories in a fashion that will cut costs by tens of millions of dollars this year alone. These actions will enable the Department to meet its target of $1.4 billion in cost reduction at the laboratories over five years, which suggests to us that a more ambitious goal should be set.[3]

A summary of the Department's laboratory reform initiatives is provided in Box 1 on page 8. As of March 1996, the Department projected that its productivity improvement efforts would result in more than $1.7 billion in savings over five years through significant reductions in unnecessary administrative costs across the laboratory system.

This document will provide the framework for achieving greater efficiencies and productivity from the laboratories. It was developed under the auspices of the Laboratory Operations Board to help the Department and the Nation get the most from the DOE laboratory system. It is responsive to the specific direction of President Clinton to the Department of Energy, Department of Defense, and National Aeronautics and Space Administration "to clarify and focus the mission assignments of their laboratories" for the purpose of sustaining and enhancing the service of these R&D institutions to the Nation's long-term needs.[4]

[3] *Report of the External Members of the Department of Energy Laboratory Operations Board*, Secretary of Energy Advisory Board, October 26, 1995, p. 3.

[4] Statement by the President, Future of Major Federal Laboratories, Office of the Press Secretary, September 25, 1995; this directive was among those announced in response to the Interagency Federal Laboratory Review, Office of Science and Technology Policy, May 15, 1995.

Elements of the Plan

This plan outlines a vision and a set of management principles that will guide actions to reform the laboratories. It provides detailed information on the Department's missions and the laboratories' roles in those missions in order to provide a basis for sound management decisions.

Volume I provides an overview of how the Department uses the laboratories. It describes the major mission objectives that the Department executes through its laboratories, it depicts the roles of the Department's multiprogram laboratories in addressing the Department's missions, and it delineates the management principles and organizational characteristics that the Department and its laboratories will strive to fulfill into the next century. Volume I also includes mission profiles for each of the DOE laboratories. These profiles provide a concise summary of the major scientific facilities, R&D competencies, accomplishments, funding levels, and R&D relationships for each laboratory. These profiles also include a "mission footprint" for each laboratory, showing how each laboratory's R&D activities maps onto the major missions of the Department.

Volume II provides a mapping of the Department's R&D programs onto the DOE laboratory structure. Mission activity profiles are included for more than 166 discrete R&D budget functions (called Budget and Reporting, or B&R, Codes) which compose the total R&D funding that goes from the Department to its laboratories. These profiles provide a description of each mission activity, its funding history, how the funding is distributed among multiple R&D performers (DOE laboratories, academia, industry), and the level of effort for each DOE laboratory. These profiles designate the relative roles of the laboratories in carrying out each of these B&R program functions, based on their proportion of fiscal year 1995 funding.

II. Using This Plan

This plan is intended to be used as a management tool to give the Department, along with Laboratory Operations Board and the Congress, a common basis for making decisions to guide the laboratory complex towards the vision outlined in the plan. The information in the plan gives managers in both DOE program offices and the laboratories a better understanding of how their work relates and compares to other work in the Department. We expect this to lead programs and laboratories, at all levels of their organizations, to take actions to differentiate and/or integrate their activities with respect to other activities in the Department. This process will lead to sharper focus at each laboratory, greater collaboration among elements of the laboratory system, and better management.

The Department and Laboratory Operations Board will provide impetus to this process by reviewing the Department's R&D programs and the roles of the laboratories. These reviews are described in Section VI.

The information in this plan also provides Congress with information that is useful in its oversight of the Department and its laboratories. This will help the Department and Congress work together to address the complex issue of eliminating redundancies within the national laboratory system without sacrificing clear areas of R&D excellence or jeopardizing the complementary skills and diversity of approaches needed to stimulate innovation and maintain excellence.

We expect this process to result in a clearer understanding of how the Department manages the national R&D programs for which it has responsibility, and in management changes that will improve the productivity of these programs. In this fashion, the plan will help the Department and its laboratories achieve their vision of a cost-effective, world-class laboratory complex for the 21st century.

III. Mission and Vision for the DOE Laboratories

Mission of the DOE Laboratories

The mission of the DOE laboratories is to deliver science and technology-based solutions that serve the Department's national security, energy resources, environmental quality, and science missions. The laboratories develop, maintain, and apply unique, world-leading science and technological facilities and capabilities, and collaborate with industry, universities, and other Federal laboratories to pursue the Department's missions, and make their capabilities available to others in the national interest.

The Department has a simple and clear vision for its laboratories in the 21st century: The laboratories will:

- Maintain the highest standards of excellence in science and technology;
- Have well-defined roles in achieving the Department's mission outcomes;
- Be well integrated with the Nation's R&D enterprise; and
- Be recognized as highly efficient and cost effective research institutions.

Excellence in science and technology. The laboratories must be world class in all of the areas of science and technology that they pursue. The Department will follow the principle of supporting the best performer of R&D for the particular work. Investments in the laboratories will be focused to ensure that each laboratory has the facilities and critical mass of expertise to achieve world-class technical excellence.

Well-defined roles. Each laboratory will be focused around a small number of missions and will have distinctive technical competencies that support those missions. Major investments in the laboratories will be disciplined around those areas. The laboratories will be well linked with each other, and will team with other laboratories whenever appropriate to bring complementary competencies to bear on complex problems.

Integrated with the Nation's R&D enterprise. The laboratories will be recognized as having strong, mutually supportive links to other agencies, universities, and industry. The distinctive competencies of the laboratories will be built around the missions of the Department, but the laboratories will use these competencies to serve other customers as well. In this sense, the laboratories will be true National laboratories, managed by the Department for the

Nation. The work for other customers will be selected to reinforce the core missions and long-term vision of the laboratories. The amount of this work will increase, resulting from the Department's efforts to make it easier for the laboratories to do work for others and from the laboratories' increased cost-effectiveness.

Highly efficient and cost-effective. The laboratories will have substantially reduced overhead costs and staff not directly related to the performance of R&D. In addition, researchers will spend less time doing administrative paper-work. This change not only will provide greater value from the investment in the laboratories, but also will make the laboratories more attractive places for top scientists to work. The laboratories complex will be sized properly to perform its functions efficiently.

Reforms that are already underway at the Department and its laboratories to make the laboratories more cost-effective are described in Box 1. Issues related to the size of the laboratories are discussed in the following section. The approach the Department will take to ensure excellence in science and technol-ogy, define the mission roles of laboratories, and integrate the labs in the Nation's R&D enterprise are addressed in sections V and VI.

Box 1. Management Reforms at the DOE Laboratories

A series of actions already under way will result in the laboratories being much more cost-effective by the year 2000. The Department has:

- Reformed and dramatically reduced its directives and orders, which are the means by which the Department establishes formal requirements and guidance for the conduct of work by employees of the Department and its contractor workforce. During 1995, the Department reduced the number of orders by 50 percent (from 312 to 156) and revised the 100 most burdensome orders into user-friendly documents. The Department expects to reduce the number of orders by an additional 10 percent by September 1996.

- Pursued a graded approach to the application of environment, safety and health standards at the National Laboratories. This approach will tailor a “necessary and sufficient” set of standards to each facility at a laboratory site, rather than imposing the most restrictive standards required for a specific facility to the whole site. This process will result in a reduction in administrative oversight and the associated costs. Six pilot projects were successfully conducted during 1995; in January 1996 the Secretary authorized the expansion to all laboratories on a non-mandatory basis (with some limitations for Defense Nuclear Facilities).”

- Begun to move from a system of self-regulation to a system of external regulation. The Department’s existing complex system of self-regulation emerged from the Manhattan Project, the Atomic Energy Commission, and Congressional actions related to the urgency of the nuclear weapons mission and the need for secrecy at the weapons production complex. An advisory committee on external regulation provided its findings to the Department in 1995. A departmental working group was established to evaluate these findings and has been tasked with identifying an internal safety management system, which may incorporate the use of external regulators and/or regulations. The final report of this working group will be submitted to the Secretary on July 31, 1996.

- Begun reform of the audit/appraisal process, which includes business practice reviews; technical reviews; and environment, safety, and health reviews conducted by the Department and other review groups. The Department’s pilots have drastically reduced the number of reviews. During the pilot period (April 1995 to April 1996 for 16 laboratories) the Department reduced the number of business practice reviews from 324 to 21, person-days of effort from 28,000 to 9,300, and costs from $10.2 million to $2.8 million.

- Revised procurement procedures. The Department’s M&O contractors previously had been expected to conform to Federal purchasing principles and practices. In 1995, the Department replaced this system with one based on the use of best commercial practices. The Department and its contractors are now working to identify and share best commercial procurement practices.

In addition, the DOE laboratories have eliminated unnecessary administrative functions and reengineered processes to cut costs. For example, the National Renewable Energy Laboratory has cut its subcontracting process from 140 steps to 40 steps, which has reduced the cycle time for contracting from 460 days to 35 days and enabled the lab to reduce its procurement workforce by 32 percent. Similarly, the Pacific Northwest National Laboratory’s laboratory-wide reengineering effort launched during 1995 will cut administrative costs by 30 percent ($60 million) in two years. Initiatives such as these are enabling the laboratories to cut overhead costs and enhance productivity. As of March 1996, cost-cutting at the DOE laboratories was expected to result in more than $1.7 billion in savings by the year 2000.

IV. Sizing the Laboratory Complex

A key area of discussion in recent years has been the overall size of the DOE laboratory complex. The Task Force on Alternative Futures for the DOE Laboratories, for example, stated that it believed that the National laboratory system is oversized for its current mission assignments, citing inefficiencies from current management practices, excess capacity associated with nuclear weapons design, and political considerations that have inhibited downsizing and reconfiguration.[5]

The Department is currently actively downsizing the laboratories by streamlining its management practices. In May 1995, as part of its Strategic Alignment Initiative, the Department set a goal of a 10 percent reduction in contractor employees at the Department's laboratories over a five year period. This would amount to a cut of approximately 5,900 employees from a fiscal year 1994 laboratory workforce base of approximately 59,000. Consistent with other elements of the Strategic Alignment Initiative, the objective is to eliminate unnecessary administrative functions while preserving direct research positions to the extent possible. As a result, the ratio of direct research staff to indirect administrative staff will increase over time.[6] As of March 1996, the Department and its laboratories have identified approximately 6,500 laboratory positions that will be eliminated as a result of administrative cost-cutting efforts by the Department as well as programmatic cuts by Congress. These cuts are equivalent to closing a large laboratory. These efforts suggest that workforce levels at the Department's laboratories will be reduced by more than 10 percent by the year 2000.

Another part of the Strategic Alignment Initiative is reducing the size of the DOE Federal workforce, many of whom are involved in overseeing the laboratories. At the end of fiscal year 1995, the Department's personnel ceiling was 14,057 employees.[7] This number will be reduced to 10,874 by the end of fiscal year 1998.

[5] Secretary of Energy Advisory Board, Task Force on Alternative Futures for the Department of Energy Laboratories, *Alternative Futures for the Department of Energy National Laboratories*, Washington, Department of Energy, February 1995, p. 10.

[6] These actions are consistent with President Clinton's directive "to achieve all possible savings [at Federal laboratories] through streaming and management improvements before productive R&D programs are sacrificed." op. cit. Statement by the President, September 25, 1995.

[7] This number excludes people employed by the Power Marketing Administrations and the Federal Energy Regulatory Commission.

With regard to concerns about excess capacity associated with nuclear weapons design, the Administration's decision to pursue a comprehensive Test Ban Treaty has reinforced the need for the weapons design labs. In the absence of testing, independent technical review and analytic capability becomes more important. President Clinton's statement of September 25, 1995 emphasized the importance of DOE's Science-Based Stockpile Stewardship program and concluded that "the vitality of all three DOE nuclear weapons laboratories will be essential."[8]

The size of the laboratory complex depends on the funding that Congress allocates to perform each of the Department's missions; the decisions that each of the Department's programs makes on how best to execute their mission among the laboratories, universities, and the private sector; and the extent of work that other agencies and the private sector organizations choose to support at that laboratory. If funding for the Department' missions shrinks, there are two general downsizing options: reducing the number of laboratories, or reducing the size of each laboratory.

By reducing the number of laboratories, it is possible, in principle, to eliminate the institutional costs of these laboratories. Closing a laboratory also dramatically demonstrates seriousness about cutting costs. Because the laboratories represent substantial investment in scientific equipment and human capital that is difficult to rebuild, however, closing a laboratory is a largely irreversible step that precludes rebuilding the capability should national needs change. It is also often resisted by Congressional delegations and local stakeholders. And many of the cost-savings may be illusory, especially since there may be continuing Federal responsibilities to decommission facilities or remediate environmental degradation. Moreover, it is not clear that it is more cost-effective to conduct the same level of programmatic activity at a smaller number of large laboratories than at a larger number of medium sized laboratories. For these reasons, President Clinton stated "While it would be easy to destroy premier Federal laboratories through severe budget cuts or senseless closures, that is not a path this Administration will follow."[9]

Downsizing in place has the advantage of being reversible and easier (although not painless) politically. When done through reengineering, it is possible to cut selectively the size of the administrative staff while preserving the technical work. Downsizing in place also occurs naturally as funding for

[8] Statement by the President, Future of Major Federal Laboratories, Office of the Press Secretary, September 25, 1995; this directive was among those announced in response to the Interagency Federal Laboratory Review, Office of Science and Technology Policy, May 15, 1995.

[9] Ibid

programs shrinks. If funding for DOE programs shrinks, the programs are likely to consolidate activities at a smaller number of laboratories to ensure that a critical mass of competence is preserved to sustain world-class performance in those areas. This would result in some multiprogram laboratories serving fewer programs. As laboratories fall below a critical mass, become less cost-effective performers of R&D, or clearly have a poor long-term funding prospects, they become candidates for closure. In this regard, the Department is examining many of its smaller laboratories to determine if they are candidates for closure, privatization, or alternative contracting mechanisms.

Although the short-term forecast is for increasingly tight DOE budgets, the long-term picture suggests that the Nation's overall (public and private) support for science and technology will remain steady, if not actually grow. The Nation's economy is expected to grow, as is the technological intensity of the economy, as measured by R&D as a percentage of gross domestic product. There will likely continue to be a need for publicly supported R&D and scientific user facilities to meet national needs, particularly if long-term industrial R&D remains under pressure. The size of the Department's laboratories 5, 10, or 15 years from now will depend to a considerable extent on whether these institutions are cost-effective performers of R&D in the public interest.

V. Missions of the Department and Roles of the Laboratories

The Department of Energy has four major missions: national security, energy resources, environmental quality, and science.[10] A fifth mission, economic productivity, is a derivative outcome of work in each of the four major mission areas. These missions have been assigned to the Department by Congress. The major goals, strategies and success indicators for each of the Department's mission areas are described in the Department's April 1994 Strategic Plan, *Fueling a Competitive Economy*.

It is important to distinguish between the roles of the Department and the roles of the DOE laboratories with regard to major public missions. While the Department has clearly defined statutory missions, this is not the case with the DOE laboratories. Rather, the laboratories have capabilities that can help the Department execute these missions, and which also can help other government agencies meet their mission objectives (see Box 2). Capabilities for meeting the Department's R&D missions also exist in academia and the private sector. How the Department uses the DOE laboratories, academia, and industry to accomplish its R&D missions varies substantially from mission to mission (see Box 3). It also varies substantially across various elements within a single DOE mission area. (Figures 1 and 2)

Figure 3 provides a simplified portrayal of the connection between the missions of the Department and the R&D capabilities in DOE laboratories, academia, and industry. Each of the four missions of the Department have a significant R&D component. These R&D programs define specific problems that must be tackled to serve each mission area. Senior departmental officials and their program managers—with input from appropriate advisory groups—determine where the best solutions to these problems can be found within academia, DOE laboratories, and the private sector. Funding then is provided from the multiple budgetary elements (B&R codes) that constitute each mission area.

The general principle used by the Department's senior officials and program managers is to invest in the most effective R&D performer for the research

[10] The Department's April 1994 Strategic Plan describes these missions as "Business lines," and identifies the science mission as the "Science and Technology" line. For the purposes of this report, however, the "technology" component of this mission is removed from the title because technology is an inextricable element of the Department's national security, energy resources, and environmental quality missions.

Box 2. Work For Others

The Department's laboratories perform reimbursable work for other Federal agencies and for other sponsors, including the private sector. This work, termed "Work for Others" (WFO), must be compatible with the Departmental mission work conducted at the laboratory, and must be work that can not reasonably be performed by the private sector. WFO accounts for between 12 percent to 22 percent of the funding for the Department's multiprogram laboratories. Total WFO funding in fiscal year 1995 was $962 million. Figure 4 shows the distribution of WFO funds at the nine DOE multiprogram laboratories. The nature of WFO ranges from long-term work for other agencies, to short term work for industrial clients. Some of the significant long-term work includes:

- The Department of Defense sponsored about 56 percent of the total WFO funding in fiscal year 1995, This work included development of weapons, transportation, command and control and detection systems, systems analysis and risk assessment, and environmental remediation of hazardous materials.
- The Nuclear Regulatory Commission has for a long-period relied on DOE laboratories for research and analysis of reactor safety systems.
- The Department's laboratories win peer reviewed awards from the National Institutes of Health for investigations into biological processes and genetic material. This work supplements the DOE-supported work into the health effects and medical applications of radiation and related fundamental biological work.
- A small but growing amount of work is performed by the laboratories for industrial sponsors.

The Department has been working to make it easier for other organizations to use the DOE laboratories. The Department is taking steps to reduce the administrative burden placed both on the laboratories and on customers.

activities that need to be accomplished. As determined by DOE program and management reviews, universities often are selected for basic research that can be conducted by individual and small groups of investigators, industry often is selected for the development of specific technologies, and the DOE laboratories are selected for the following:

- R&D for which national security requires a high degree of security;
- Building and operating large scientific facilities that are beyond the scope of what industry or universities can afford or sustain;
- Research that relies on multidisciplinary expertise and an ability to address large-scale, complex problems; and
- Mission-focused research that requires results with more urgency than can be anticipated from other R&D performers.

Each of the DOE mission areas has different needs and allocates its resources among laboratories, universities, and industry in a different way. The DOE

Box 3. Role of Universities in Performing Research for the Department of Energy

The Department of Energy and its predecessor agencies have long used universities to perform research for the Department and to manage research programs both at Department-owned facilities and at universities. The majority of DOE laboratories are managed either by a university or a consortium of universities. These include both multiprogram laboratories (Argonne, Lawrence Berkeley, Lawrence Livermore, Los Alamos National Laboratory, Brookhaven) as well as program-dedicated laboratories (Ames, Princeton, Thomas Jefferson, Fermi, Stanford, and ORISE). Many of these laboratories are co-located with or near major universities, and many of the laboratories were established to serve the university community with large-scale scientific facilities that did not fit within the university site or management structure.

The Department's extensive relationship with academia helps make the rigor and intellectual inquiry of academe an integral part of the laboratory community. Many university professors and officials serve on review and advisory committees for the Department and its laboratories, assuring a two-way flow of information on the Department's needs and universities capabilities, and exposing the Department to the concerns of academia.

A significant fraction of the Department's basic research goes to universities through grants to academic researchers. This is the preferred mode for research that can be done by individual professors or a small team of students and faculty. Research proposals are solicited, peer reviewed, and funded.

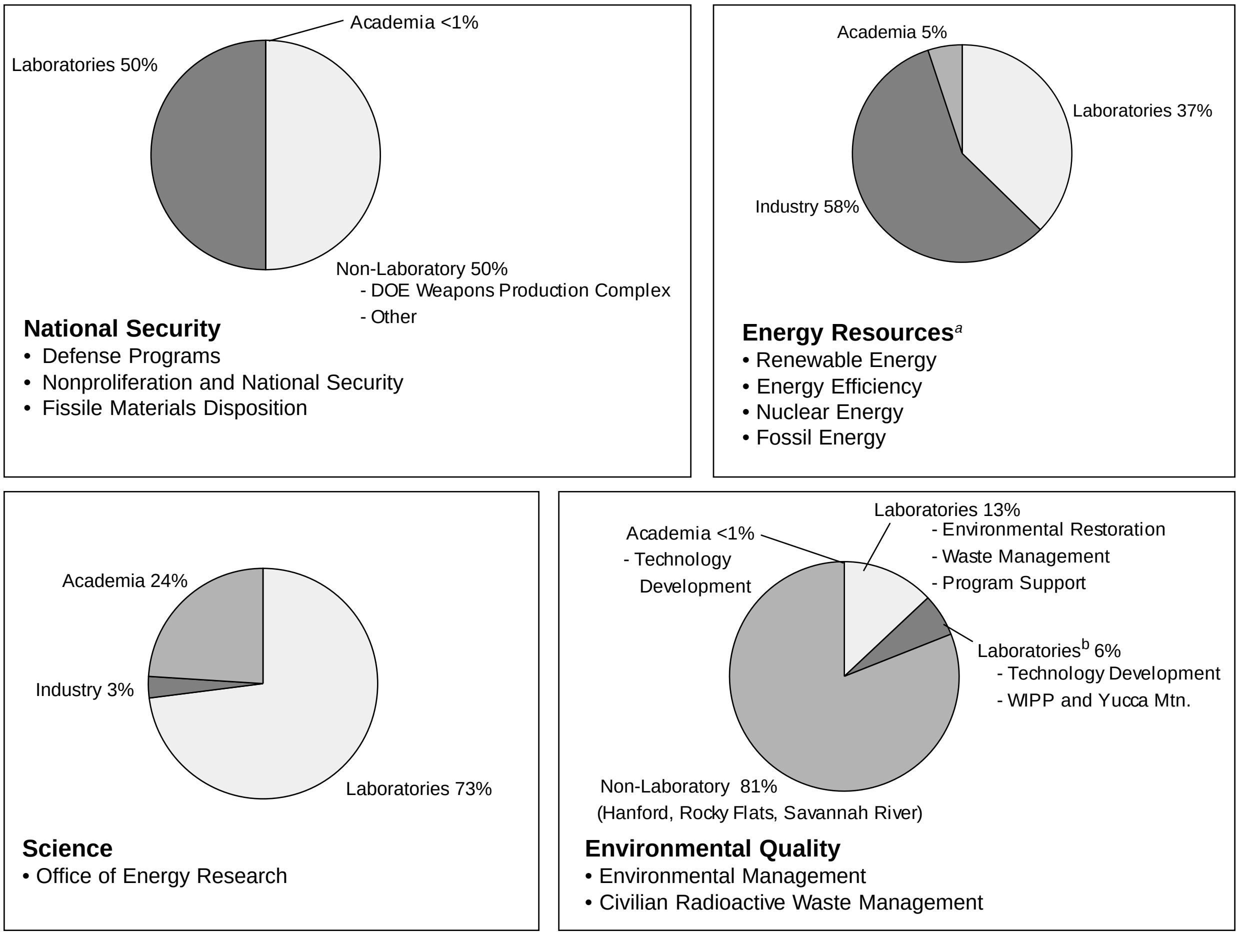
A major mode of interaction with universities is through the Department's scientific user facilities. The Department supports university researchers to take advantage of these instruments that are essential to extending the frontiers of science. In certain scientific disciples, the most creative research and instruction of students can only be done at these large facilities. The Department operates these for a broad community of scholars. The Department support ranges from providing funds for the construction of detectors, information processing devices and computers, to providing funds to individuals and small groups to use these facilities.

The Department also supports university researchers through cooperative programs funded through the laboratories. In preparing the research plans required for the receipt of funds, laboratory program managers describe the work that will be performed and whether subcontracts with industry or grants to universities are part of the plan. Cooperation with university researchers is encouraged and professors and students are frequent visitors to the laboratories for short or extended stays, as well as performing research at their home institutions.

The Department supports a number of university students and faculty through grants directly to their institutions. This may be through graduate or faculty fellowship, the provision of specialized instrumentation, or funds for training and research stays at the National Laboratories. The Department's association with the academic community is an integral part of the Department's operating mode of combining basic research with practical applications.

laboratories are used most extensively in pursuit of the Department's national security and science missions, with nearly 100 percent and 73 percent, respectively, of the R&D funds in these two mission areas being expended at the DOE laboratories and facilities. In contrast, only about 45 percent of the Department's approximately $315 million R&D program in the Environmental Quality mission area and 37 percent of the Department's $1.6 billion Energy

Figure 1. Utilization of the Laboratories Varies by Mission

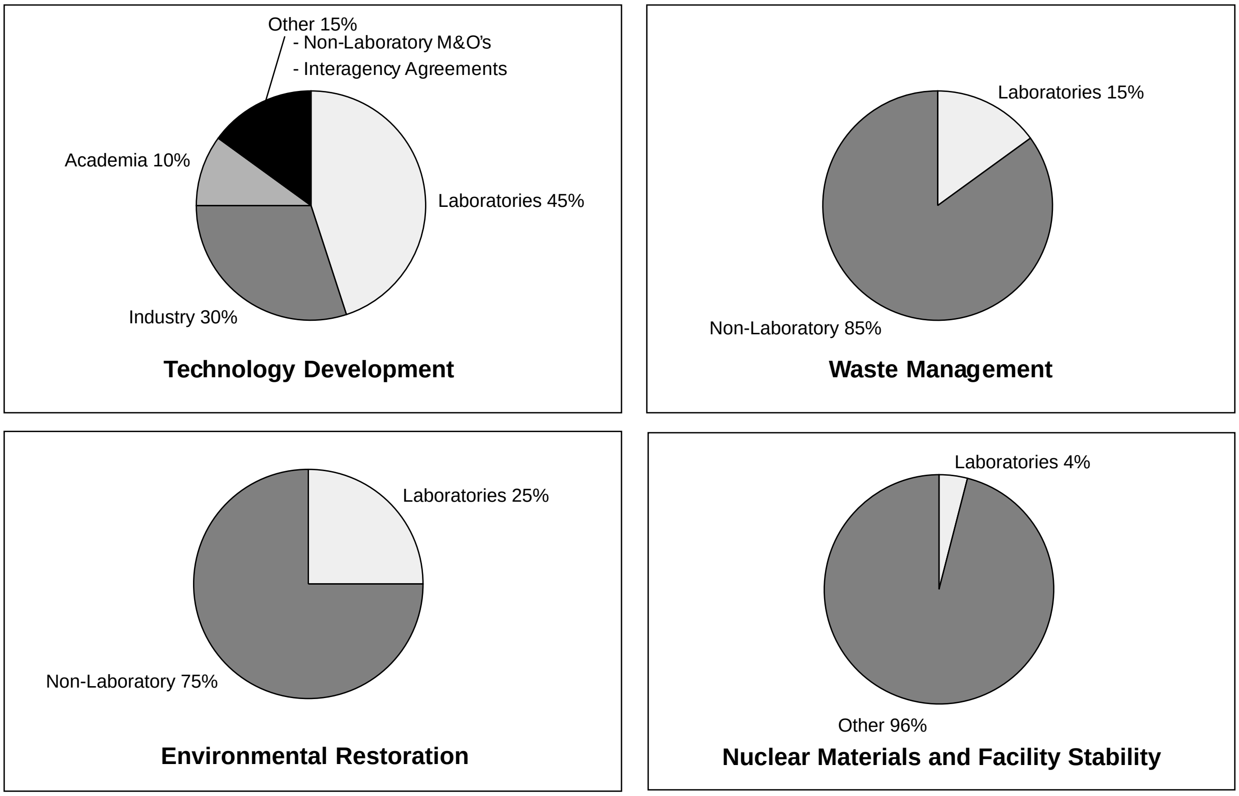


[a] Does not include the Power Marketing Administration, Strategic Petroleum Reserve, and Energy Grant programs.
[b] Laboratory portion does not include site cleanup, waste management, and ES&H activities.

Resources R&D program are conducted at the DOE laboratories. Nearly 20 percent of the activity at the DOE multiprogram laboratories is supported by other Federal agencies or private organizations, to take advantage of capabilities developed for DOE missions.

The DOE laboratories do not receive their funding in large, line item allocations. Rather, each laboratory budget is a composite resulting from individual funding decisions made by the Department's senior management and the program managers who preside over the many mission activities (B&R codes) which define the R&D component of the Department's budget. This approach gives the Department's program managers the responsibility for determining the best mix of R&D performers to meet the Department's mission requirements. A consequence of this distributed approach to funding is that the deci-

Figure 2. Lab Utilization Varies Within Missions—Example: Environmental Management



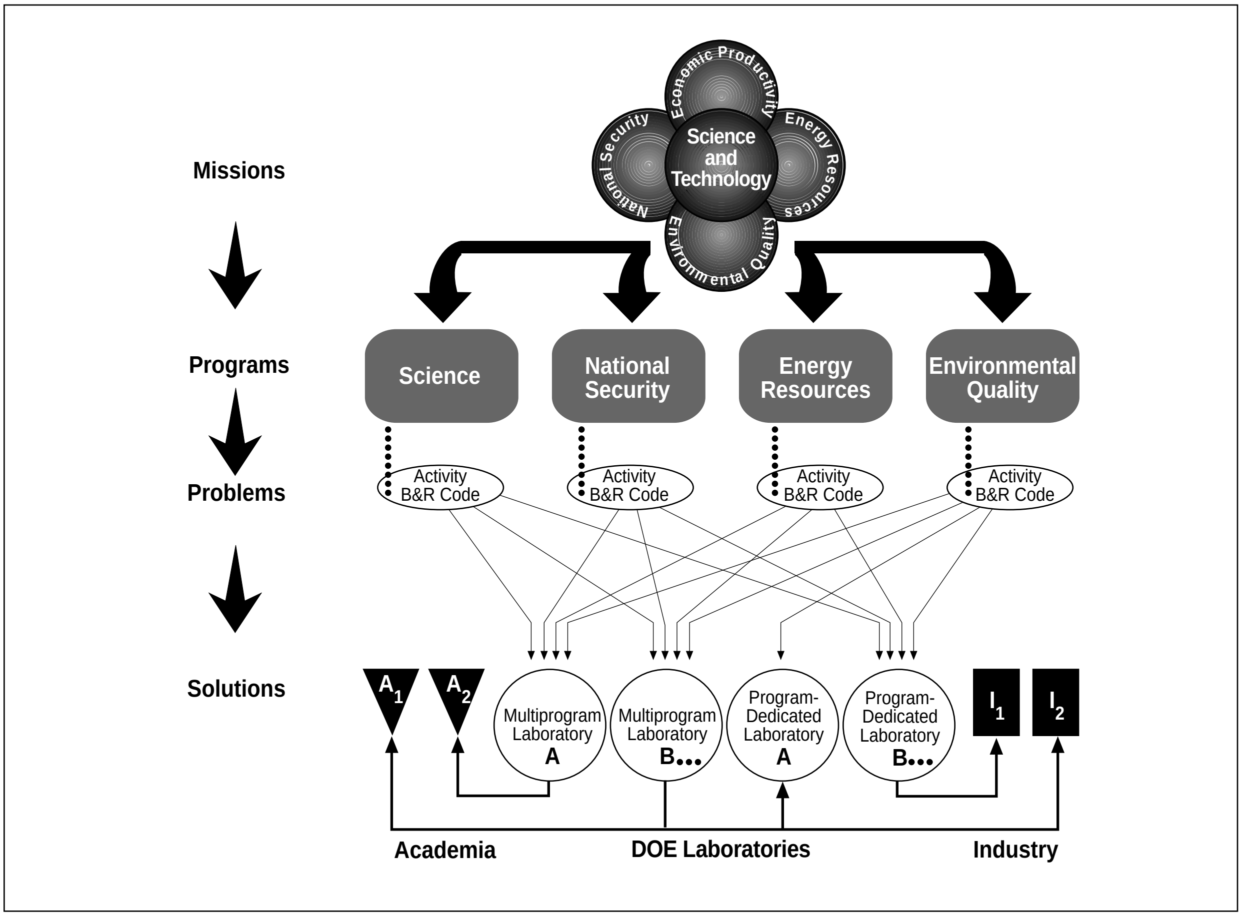
sions in the DOE programs exert a major influence on the shape of the laboratories and the quality of their work, and therefore the quality of these decisions strongly affect the quality of the laboratories.

Sharpening the Focus of the Laboratories

A key set of issues is whether the Department's missions should be focused at a small number of laboratories and whether each laboratory's work should be tightly focused on a small number of missions. As noted above, the Department has been urged to establish sharper missions for the DOE laboratories. Focusing mission resources at a particular laboratory can:

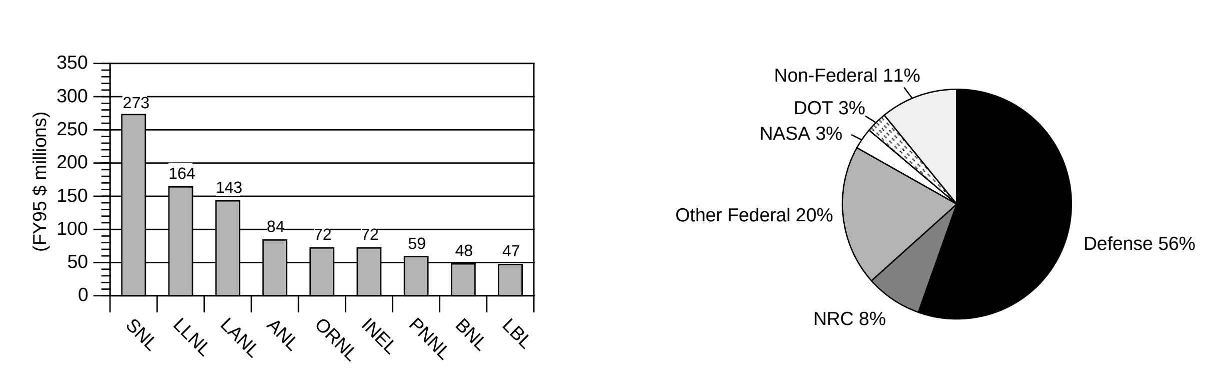
- Ensure a critical mass of effort and investment in facilities focused on that mission.
- Reduce the costs in coordinating the mission's R&D effort(s).

Figure 3. Simplified Diagram of DOE R&D Funding Process



This diagram shows in simplified form how the Department of Energy's R&D missions are accomplished through academia, industry, and the DOE laboratories. Each mission area comprises many different programs. These programs define the scientific and technical problems that must be addressed in each mission area. Each mission area has multiple activities, which for budget purposes are represented by Budget and Reporting (B&R) Codes. The funding arrows in the figure are exemplary of how program managers with responsibility for a sample B&R code for each mission area distribute funding to multiple R&D performers within the DOE laboratories, academia, and industry. The figure also shows that funding flows from the labs to academia and between the labs and industry. By no means does this diagram attempt to show all of the major funding arrows between the Department and the DOE laboratories, academia, and industry, or funding from other agencies and the private sector to the labs.

Figure 4. Distribution of WFO Funds at the Nine DOE Multiprogram Laboratories



- Make it easier to understand and evaluate the work of the laboratories as it relates to that mission.

However, there are reasons why too narrow a mission focus for the Department's multiprogram laboratories would be undesirable:

- The technical capabilities that the Department requires to accomplish its missions in the most cost-effective way may not be available in a single or few laboratories.
- The technical challenges for accomplishing the Department's missions change over time, requiring the use of laboratories with different capabilities. A capabilities developed at a laboratory to support one mission may be vital to another mission later on.
- Tightly focused mission assignments likely would sacrifice one of the greatest strengths of the DOE laboratories—their ability to apply broadly divergent disciplines to complex R&D challenges. Multidisciplinary capabilities have allowed the DOE laboratories to pioneer new approaches to many R&D challenges and have helped establish new fields of scientific inquiry.[11]
- Research prospers in an environment that allows the best ideas—no matter what their source—to be proposed, competitively evaluated, and funded. Restricting proposals for mission work to a small number of laboratories would artificially limit competition for the best ideas.

[11] The Department's multiprogram laboratories have a rich heritage of providing major R&D contributions to the Nation by taking expertise developed in pursuit of one national mission and applying it in a new, innovative fashion. For example, sophisticated computational capabilities and molecular biology expertise at the DOE laboratories spurred development of the Human Genome program.

There is an inherent tension between the need for strategic focus on the one hand, and the need for flexibility and diversity on the other hand. The management imperative for the Department is to achieve the optimum balance between these two needs.

There is also a tradeoff between having laboratories focused around a mission or focused around technical competencies. If laboratories are each focused around a single mission, they each will need broad technical expertise to support those missions, leading to duplication of technical expertise across the laboratory complex. On the other hand, if laboratories are each focused around a technical competency, several laboratories will be needed to accomplish each mission. For this reason, the DOE laboratories (as well as any other system of research institutions) may always appear to contain either redundant capabilities or laboratories without sharply focused missions.

There are circumstances where it is desirable to focus a laboratory's activities around a single mission. DOE supports several such mission specific laboratories. They also are profiled in Section VIII.

The approach that the Department believes will meet the requirement to increase strategic focus at the multiprogram laboratories, while also preserving their competitive strength as multiprogram institutions, is to focus investment in the laboratories around their principal missions, but to allow laboratories to contribute to other missions when they have clear capabilities to do so.

VI. Managing Mission Roles in the Laboratories

The Department has two general ways of managing mission roles in the laboratories. One is by focusing on the laboratories themselves; the other is by focusing on the decisions each DOE program makes to choose laboratories to perform its mission. The following subsections describe the mission roles of the laboratories from these two perspectives. The next subsection addresses the principal roles of each of the multiprogram laboratories and the following subsection addresses principal performers for each DOE program. The final subsection describes the principles and processes the Department will follow to assure the proper degree of mission focus in the laboratories.

Mission Roles of DOE's Multiprogram Laboratories

Many of the Department's multiprogram laboratories are involved at some level in all four of the Department's major missions. Upon a superficial examination, the multiprogram laboratories might appear indistinguishable or to contain major redundancies. Upon closer examination, however, it becomes clear that each of the Department's multiprogram laboratories is focused around a small number of missions that generally rely on shared competencies.

For each of the Department's missions (national security, energy resources, environmental quality, and science), an involved laboratory can be viewed as having any one of the following roles, based on the relative level of funding that they receive in the mission area:

- **Principal Role—**A laboratory in this category receives more than 35 percent of its funding from this mission. For example, the laboratories that have the national security mission as their principal role are the three nuclear weapons laboratories: Sandia National Laboratories, Lawrence Livermore National Laboratory, and Los Alamos National Laboratory. The national security mission represents a major strategic thrust for the laboratories and they have a prominent position within the Department's overall program.
- **Major Contributing Role—**These institutions provide substantial, continuing contributions in pursuit of high-level mission objectives. Between 10 and 35 percent of the budget of each laboratory is devoted to this mission.

- **Specialized Participating Role—**These laboratories are involved in a particular mission area at a low level (less than 10 percent of total laboratory funding) based on a specialized capability or superior approach to addressing particular mission objectives. Involvement in the mission area tends to be derivative of capabilities that have been developed through Principal or Major Contributing roles for other mission areas.

Table 1 delineates the roles of the multiprogram laboratories (Principal, Major Contributing, and Specialized Participating) in the Department's missions.[12]

The Department and laboratories use the institutional and strategic planning processes (see Box 4) as a mechanism to discipline the mission roles of the laboratories.

[12] These roles reflect the laboratories' view of their focus according to the proportion of their funding. They are not based on the quality of output. Over time, however, these roles should be assigned based on qualitative measures of performance.

Box 4. Institutional Planning

Institutional Planning is a departmental process for reviewing each laboratory's programs, institutional needs, and future initiatives. It is done annually at each laboratory and provides a forum for the Department's Program Secretarial Officers and the laboratory management and contractor to address issues and programmatic initiatives in the context of the laboratory as an institution. It is a comprehensive overview of a laboratory, including the laboratory's mission, strategic plan, issues, scientific initiatives, research programs, technology transfer, science education, environment, safety and health activities, human resources, and facilities.

The annual planning cycle for each laboratory starts with a draft institutional plan prepared by the laboratory, which reflects policy guidance from the Department. Following headquarters review of the draft plan, an institutional planning on-site review is held at the laboratory. Participants in the review include the DOE programs that have major investments in the laboratory, as well as the laboratory director, operations office manager, and the operating contractor. Following the review, the Department provides guidance and action items resulting from the review to the laboratory. This letter contains preliminary approval for the draft plan as the final plan, after incorporating substantive comments from the Department. Approval indicates that the plan presents laboratory activities desired by the Department; that mission assignments are appropriate for the laboratory; and that program emphasis, external interactions, level and nature of the coming budget year, and work for other activities are appropriate. A final plan is typically due three months after the on-site review.

Table 1. Applied Mission Roles of DOE's Multiprogram Laboratories[a]
(Proportion of Laboratory Effort Directed to Mission Area)

Mission	Principal Role	Major Contributing Role	Specialized Participating Role
National Security	Sandia National Laboratories Los Alamos National Laboratory Lawrence Livermore National Laboratory		Pacific Northwest National Laboratory Oak Ridge National Laboratory Brookhaven National Laboratory Argonne National Laboratory Idaho National Engineering Laboratory
Energy Resources	Oak Ridge National Laboratory Argonne National Laboratory	Lawrence Berkeley National Laboratory Sandia National Laboratories Pacific Northwest National Laboratory	Los Alamos National Laboratory Lawrence Livermore National Laboratory Brookhaven National Laboratory Idaho National Engineering Laboratory
Environmental Quality	Pacific Northwest National Laboratory Idaho National Engineering Laboratory	Argonne National Laboratory Sandia National Laboratories	Oak Ridge National Laboratory Lawrence Livermore National Laboratory Los Alamos National Laboratory Lawrence Berkeley National Laboratory Brookhaven National Laboratory
Fundamental Science[b]	Brookhaven National Laboratory Lawrence Berkeley National Laboratory Argonne National Laboratory Oak Ridge National Laboratory	Pacific Northwest National Laboratory Los Alamos National Laboratory Lawrence Livermore National Laboratory	Sandia National Laboratories

[a] Based on proportions of fiscal year 1995 laboratory new budget authority as provided in the DOE mission footprint and on data from Volume II Mission Activity Profiles.

[b] Because Science and Technology crosscuts all of the mission support activities at DOE, the term here is modified to include those fundamental research efforts primarily supported by the Office of Energy Research that are key to defining the Laboratory roles in basic research. These activities primarily are directed to the fundamental properties of matter, materials, and biological systems germane to DOE's missions.

Primary Performers for DOE Missions and Programs

The second way of addressing the mission roles of the laboratories is to examine which laboratories the DOE programs look to as the primary performers of their missions. In general, a discrete set of laboratories conducts the overwhelming majority of laboratory-based R&D in each of the Department's programs. Table 2 shows the primary performers for each major element of the Department's missions.

For each program, the primary performers are the ones in which the program makes enduring and strategic investments. Most programs also fund other laboratories to take advantage of special capabilities or facilities that were developed in support of other missions.

As Table 2 shows, the science mission often uses more laboratories to perform its missions than do the other missions. This reflects the fact that science underlies virtually all of the Department's missions. Some elements of the science mission are deliberately integrated with and co-located with other

Table 2. Primary Performers for DOE Missions and Programs

Mission	Program	Laboratories
National Security	National Security[b]	SNL, LANL, LLNL
	Naval Reactors	BAPL, KAPL
Energy Resources	Fossil Energy	METC/PETC
	Renewable Energy	NREL
	Energy Efficiency	ORNL, NREL
	Nuclear Energy	PNNL, ANL
Environmental Quality	Civilian Radioactive Waste	PNNL, SNL, LANL, LLNL
	Environmental Science and Technology	INEL, METC, SRTC, PNNL, SNL, ORNL
Science	High Energy Physics	FNAL,[a] SLAC,[a] BNL[a], LBNL
	Nuclear Physics	TJNAF,[a] BNL,[a] LANL,[a] ANL,[a] ORNL[a]
	Plasma Physics	PPPL[a]
	Environmental Sciences	PNNL[a]
	Biological Sciences	LBNL, LANL, LLNL, ANL, BNL, ORNL
	Computational Sciences	Distributed,[c] LBNL[a]
	Basic Energy Sciences	Distributed,[c] ANL,[a] BNL,[a] LBNL,[a] LANL, ORNL[a]

[a] Location of major user facility for program.
[b] Includes the Offices of Defense Programs, Nuclear Nonproliferation, and Materials Disposition.
[c] Computational sciences and basic energy sciences work is distributed among many laboratories because they are integrated with other research programs.

missions in order to support those missions. For example, materials research and computing need to be closely linked with R&D in both the Department's applied missions and with other areas of science.

Section VII of this Plan describes the major outcomes for each of the Department's missions and the roles of the Department's laboratories in performing those missions. The way each program uses its laboratories is expanded on in that section.

Principles for Managing Laboratory Mission Roles

As described earlier, there are advantages and disadvantages for having the laboratories be more narrowly mission focused. The key goal to keep in mind in managing the mission roles of the laboratories is to achieve the best value for the taxpayers. This means in general that program managers should fund the most cost-effective performers of R&D, whether it be laboratories with a traditional role in a mission area, laboratories with applicable capabilities derived from work in other mission areas, or universities or private sector firms.

In making these decisions, however, the Department also needs to consider the institutional effects on the laboratories. The Department has a responsibility to ensure that investments in the laboratories are focused in a way that achieves the critical mass of expertise required for excellence and that avoids redundancies. The Department also has a responsibility to ensure that the unique and critical capabilities that the Department will need in the future are maintained, that there is a degree of stability in the laboratories' funding, and that facilities that will not be highly valuable in the future will be shut down.

Choosing the optimum management approach is more art than science and requires the judgement of DOE program managers, as well as the cognizant secretarial officer for each laboratory. In some cases, the best value for taxpayers can be achieved by focusing a mission activity at a single laboratory. In other cases, the best value can be obtained by drawing on capabilities of many laboratories in an integrated, multi-laboratory program. In yet other cases, it is desirable to support two different groups that will use alternative approaches to the same problem. Although it is not useful to write precise rules for how to manage these programs, there are a few general principles that should be followed, and each DOE program should have a clear and defensible rationale for its mode of management.

The general principles to be followed include: [13]

- The Department will focus its new investment in research facilities in the primary performers for each mission area.
- It will be rare for a laboratory with a Specialized Participating role in a mission area to be able to significantly expand its role. Expansion might occur, however, if the technical needs of a mission change in a major way, or if the laboratory created a significant new technical opportunity through a breakthrough development.
- Activities at laboratories that are not best-in-class and are not essential for the future missions of the Department will be eliminated or consolidated with activities at another laboratory.
- DOE will fund and manage programs at the laboratories, not individual projects. The strength of the laboratories vis-a-vis universities is in their ability to put together coherent programs, especially those involving multi disciplinary teams.
- The Department will seek to maximize opportunities to operate the laboratories as a system (or a set of mission subsystems), building on the complementary strengths among the laboratories and eliminating unnecessary redundancies.

The Department and the Laboratory Operations Board will jointly review the DOE program management systems with regard to their rationale for the mix of R&D performers (DOE laboratories, universities, or industry) they use to carry out the missions. In particular, these reviews will ask if the work would be better concentrated at a smaller number of R&D performers or make better use of capabilities in universities and industry. They will also ask if the right degree of management is delegated to the laboratories.

The external members of the Laboratory Operations Board also will document and review the mechanisms used throughout the Department for evaluating the scientific and technical merit of the work at the laboratories. These mechanisms include advisory boards to various DOE programs, advisory boards to laboratories and individual programs within laboratories, as well as peer review panels established for specific proposals. The reviews will determine how the existing system compares to that of other R&D organizations and the extent to which changes are needed.

[13] These principles are appropriate primarily for the multiprogram laboratories, since program-dedicated facilities (for example, the Fermi National Accelerator Laboratory) have a singular mission focus.

The Department and the Board will also review the institutional and strategic plans for the multiprogram laboratories to determine how these may better contribute to the needs of the Department. The multiprogram laboratories will organize their institutional planning efforts primarily around their Principal and Major Contributing roles in the Department's missions. The Department and the Board will closely examine the laboratory's Specialized Participating mission roles to ensure that the contributions of the laboratories in these areas are truly distinctive.

VII. Major DOE Mission Outcomes and DOE Laboratory Roles

The American public and Congress need to know what benefits they can anticipate receiving over the long term from their investments in the Department's R&D mission areas. These outcomes are described in the Department's Strategic Plan and in annual reports and testimony presented to Congress. For the purpose of this document, however, the major outcomes expected over the next 10 to 20 years for each of the Department's R&D mission areas are presented and a brief description is provided of how the Department manages and the role of the DOE laboratories in each mission area vis-a-vis other R&D performers. The level of effort of the DOE laboratories is presented for each mission area in terms of the Principal or Major Contributing roles that they may play.

The National Security Mission

National Goal

Achieving a significant reduction in the global nuclear danger while simultaneously maintaining a safe and reliable nuclear deterrent with a nuclear test ban in force.

Role of the Department

Managing nuclear weapons and related nuclear materials is a clear and statutory governmental responsibility. In addition to providing a high-confidence, enduring, affordable, safe, and reliable stockpile, the Department plays a critical role in supporting U.S. arms control and nonproliferation policy, as well as R&D on reactors in support of the U.S. Navy's nuclear powered fleet and power sources for spacecraft. Through its laboratories the Department provides the vital R&D expertise required to maintain and dismantle nuclear weapons, manage the disposition of weapons-grade materials, detect proliferation, and monitor nuclear treaties.

Anticipated Outcomes

Safe and Reliable Nuclear Weapons Deterrence. The Department will provide the Nation with a safe and reliable nuclear weapons stockpile based on:

- **Science-based stockpile stewardship.** The Department will be able to assess, maintain, refurbish, and certify nuclear weapons while allowing the Nation to support a zero-yield Comprehensive Test Ban Treaty. Design competence will also be maintained at each laboratory to allow the Department to incorporate new advances in weapons safety and security into existing weapons, and to respond to supreme national interests, should the need arise. The shift from nuclear testing-based certification to science-based stockpile stewardship requires new nonnuclear testing facilities and significant advances in computer simulation. Scientific and technical details of each nuclear weapon operating process must be understood well enough to maintain confidence in a stockpile aging beyond its design life and to anticipate aging issues before they compromise stockpile confidence.

- **Ensured supply of tritium for the stockpile.** This supply will be based on a dual-track strategy that will examine and compare the feasibility and cost-effectiveness of both accelerator and reactor produced tritium.
- **Reconfigured nuclear weapons fabrication capability.** A downsized, modernized complex—including the three national security laboratories, the Nevada Test Site, Pantex, the Savannah River Site, the Y–12 facility, and the Kansas City Plant—will maintain low-rate production and component assembly sufficient to extend the life of the stockpile and to provide the base for any future expansion, if required.
- **Basic capability to resume nuclear testing.** The Department will maintain the expertise and facilities needed to test nuclear weapons should testing be required by supreme national interest.

Reduced global nuclear danger. The danger posed to the U.S. and the world by nuclear weapons and nuclear materials will be significantly reduced over the next two decades by:

- **Reducing the risk of proliferation of nuclear weapons.** The Department's science-based stockpile stewardship program, strengthened by continuing R&D on nonproliferation concerns, and its test ban verification capabilities will enable U.S. support of a zero-yield Comprehensive Test Ban Treaty, which will strengthen the global nonproliferation regime. In addition, R&D on nonproliferation technologies will augment the Department's science and technology capabilities and weapons expertise and will lead to significantly greater capabilities to detect proliferation activities for nuclear, biological, and chemical weapons of mass destruction.
- **Reducing the number of nuclear weapons.** Large numbers of nuclear weapons will be safely dismantled and their components or materials stored in safe and secure facilities. Based on confidence in our nuclear weapon's stockpile, the U.S. will be in a strong position to negotiate further reductions in the stockpile. The Department also will be able to assist other nations with safe, secure dismantlement of nuclear weapons.

- **Reducing the amount of fissile materials.** Surplus weapons-usable fissile materials will be stored or eliminated, encouraging reciprocal action abroad. The Department will develop secure, environmentally sound, inspectable, and cost-effective storage for the Department's surplus fissile materials.
- **Improving the control of nuclear materials.** The Department will provide assistance to Russia and other former Soviet Union States, allowing these nations to establish effective protection, control and accountability of strategic nuclear materials within their laboratory complex. International initiatives on nuclear materials management will help diminish significantly the risks of nuclear materials diversion world-wide, and enhance global cooperation on such issues. The Department will develop more effective sensors to detect, and equipment to disable, contraband weapons. It also will develop improved capabilities to respond to nuclear emergencies.
- **Shutting down Russian plutonium production reactors.** Reduce national security threat posed by continued production of weapons-grade plutonium in Russia. The Department is working with Russia to identify options to replace its plutonium production reactors, or to convert their cores so that weapons plutonium is not produced.
- **Providing sound policy advice.** The Department's weapon and other technical expertise will provide sound advice to policymakers in national security, international energy, and science policy.

Program Management

In the national security mission, the Department seeks to preserve institutional capabilities as well as achieve programmatic R&D goals. Although some funds are spent in the universities, in collaborations with industry and other Federal agencies, the three major recipients of most of the DOE national security R&D funding are Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), and Sandia National Laboratories (SNL). The bulk of the Naval Reactors (NR) funding is concentrated in two labs, Bettis Atomic Power Laboratory (BAPL) and Knolls Atomic Power Laboratory (KAPL). All of these labs contain some of the finest research and engineering talent in the world, and they are unique and irreplaceable repositories of the expertise that underlies the U.S. nuclear weapons stockpile, and in the case of BAPL and KAPL, the navy's nuclear-powered fleet. Funding allocated to the labs depends not only on each lab's individual strengths (for example, LANL, accelerators; LLNL, lasers; SNL, microelectronics) but also on the need to comply with Congressional, Administrative, and Departmental (Defense and Energy) directives.

The national security mission requirements are tremendously challenging and require a significant level of funding to maintain the facilities and the necessary cadre of technical experts. Moreover, the extreme sensitivity of nuclear weapons work limits where work can be performed. If higher quality R&D can be performed elsewhere, funds may be spent outside these laboratories. In general, however, national security's mission and mandates, as well as the laboratories' unique capabilities, have led to a determination that the best place for DOE to spend its national security R&D funds is at its national-security–oriented laboratories. This provides the dual benefits of (1) performance of world class R&D in support of its mission requirements and (2) the maintenance of capabilities and facilities to respond to national security needs.

Because most of the work is concentrated at a few laboratories, much of the technical program management can be delegated to the laboratories. DOE headquarters focuses on policy and priority decisions.

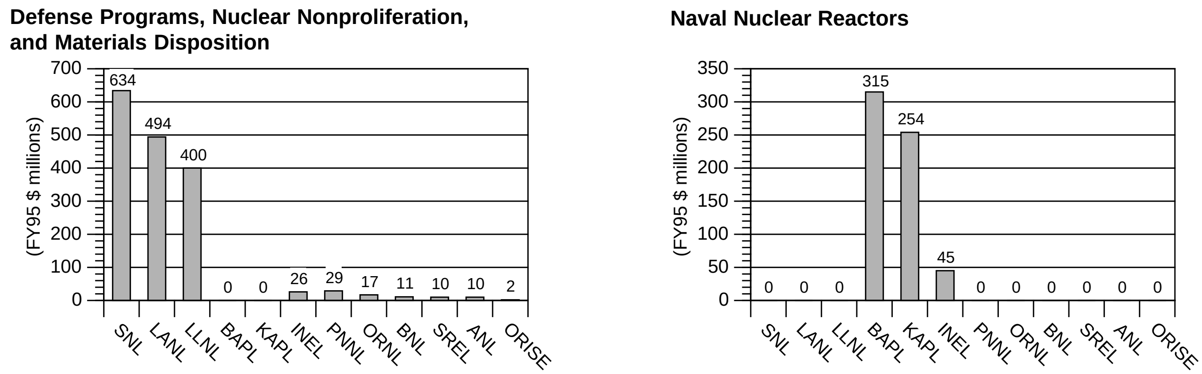
Role of the DOE Laboratories

As time elapses since the last nuclear test was conducted, confidence in the nuclear deterrent will depend increasingly on the science and technology capabilities of the Department's laboratories and other facilities to assess, maintain, refurbish, and certify the stockpile. Any part of a nuclear weapon system must be replaced before the safety, security or reliability of the system is reduced. In fact, as a safeguard for U.S. entry into a Comprehensive Test Ban Treaty, the directors of the Department's national security laboratories must report if the safety and reliability of a weapons type crucial to our nuclear deterrent could no longer be certified.

Approximately $4.5 billion (26 percent) of the Department's overall fiscal year 1995 budget of $17.1 billion was dedicated to the national security mission. Of these funds, approximately $2.3 billion (50 percent) supported R&D activities at DOE laboratories. Because of the sensitive nature of nuclear weapons research and the need for very large facilities and multiprogram interactions, very little of these R&D funds supported work in academia or the private sector.

The funding for the laboratories from the National Security mission is shown in Figure 5. The Department's three nuclear weapons laboratories—Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories—perform the majority of the DOE's national-security–related R&D. Lawrence Livermore National Laboratory is responsible for nuclear components of stockpiled weapons which it designed and is required, with Los Alamos National Laboratory, to provide certification of all stockpiled nuclear weapons. Lawrence Livermore National Laboratory pos-

Figure 5. National Security—DOE Laboratory Funds



Note: Fiscal year 1995 New Budget Authority (Operating)

sesses unique laser capabilities for laboratory simulation of nuclear explosive behavior.

Los Alamos National Laboratory is responsible for nuclear components of stockpiled weapons which it designed and is required, with Lawrence Livermore National Laboratory, to provide certification of all stockpiled nuclear weapons. Los Alamos National Laboratory possesses unique capabilities in neutron scattering required for stockpile stewardship and enhanced surveillance.

Sandia National Laboratories is responsible for nonnuclear components as well as systems integration of all stockpiled devices, and provides unique capabilities in advanced manufacturing technology, microelectronics, and photonics.

The three laboratories rely on the broad support of the rest of the weapons complex, industry, and academia to provide additional technological and research input. External scientific review bodies also evaluate the overall status and direction of the weapons program. The recruitment and retention of a world class technical staff, however, remains a critical factor in enabling the DP laboratories to accomplish their missions.

Science-based stockpile stewardship necessitates investments at these laboratories in new facilities such as the National Ignition Facility, the Dual Axis Radiographic Hydrodynamic Test Facility, and the ATLAS pulsed power machine, as well as initiatives in enhanced surveillance, computation, and engineering and manufacturing technology. Computation is particularly important. High-fidelity simulation must replace underground nuclear explosions as the integrated test bed, and must provide the link between past test data, current weapon performance, and future experiments. The nuclear weapons expertise of the three national security laboratories also is used by the Department in support of the Nation's arms control, nonproliferation, and intelligence requirements. The laboratories nuclear weapons expertise is leveraged by the DOE nonproliferation R&D program. The weapons laboratories provide the majority of the expertise needed to verify treaties, detect proliferation, and deter/detect the diversion of nuclear materials.

Another significant role of the nuclear weapons laboratories is to support non-DOE sponsors who require the specialized skills and facilities possessed by the laboratories to perform work which benefits both. The majority of this work is performed for the Department of Defense, although a significant amount of work is performed for other sponsors as well.

The Energy Resources Mission

National Goals

Help ensure that energy supply and utilization meet our short- and long-term environmental, economic, and national security goals, which are:

- Keep America secure by reducing our dependence on foreign oil.
- Improve the environment by preventing and reducing pollution related to energy production and use.
- Maximize the productivity with which we produce and consume energy.

Role of the Department

The Department of Energy is the agency in the U.S. Government with primary responsibility for addressing these goals. The Department's role, and especially that of its laboratories, however, is limited to areas where the private market does not adequately meet public needs (such as environmental protection and national security) and where public investments in science and technology address patterns of underinvestment by the private sector (such as long-term R&D). Many of the energy-related technologies in which the Department invests achieve multiple goals.

Anticipated Outcomes

- **Increased energy security**. Within the next 15 years, Persian Gulf nations may control two-thirds of the world's oil for export, America may be importing nearly 60 percent of its oil, and the U.S. trade deficit in oil might double to $100 billion a year.[14] Technology has proven to be effective in reducing the U.S. economy's oil intensity in the past, especially in the utility and industrial sectors. A key focus of effort for the future must be transportation, which is more than 95 percent dependent on petroleum. The Department's strategy for enhancing U.S. energy security includes:

—*Partnership for a New Generation of Vehicles*. Invest in advanced materials and engine technologies to design and construct by 2004 a prototype clean car that has three times the fuel efficiency of existing automobiles and very low emissions, but comparable or improved performance, safety, and cost. Invest in the development of cars and trucks that can run on alternative fuels, such as electricity, liquid biofuels, and natural gas.

—*Develop alternative fuels*. Lower the cost of alternative transportation fuels, such as liquid biofuels from crops, crop waste, and municipal solid waste, and liquid fuels from gas and coal.

—*Expand the traditional resource base*. Invest in technologies to lower the cost and increase the effectiveness of finding and extracting oil and gas, such as using advanced computing and simulation to model oil and natural gas fields.

- **Environmental Protection**. The production and use of energy causes more environmental damage than any other single economic activity. For example, the Nation's seven most energy-intensive industries—steel, aluminum, petroleum refining, chemicals, pulp and paper products, glass, and metal casting—account for approximately 80 percent of the energy consumed in U.S. manufacturing and more than 90 percent of the hazardous waste. The Department will invest in leapfrog technologies that the private sector underinvests in because of the risk or because it involves an environmental benefit not adequately reflected in market prices. The Department's strategy for reducing environmental damage related to energy use includes:

—*Cooperative plans for energy- and materials-intensive industries*. In cooperation with the private sector, the Department will develop technology roadmaps and new technologies aimed at dramatically curbing the energy use and the pollution generated by the most energy- and materials-intensive industries.

—*Reduced pollution from traditional energy sources*. About 85 percent of the energy we consume comes from fossil fuels such as coal, oil, and natural gas. Over the next decade, the Department will develop ad-

[14] *Annual Energy Outlook 1996 With Projections to 2015*, Energy Information Administration, January 1996.

vanced fossil fuel technologies that exceed new emission requirements (up to 10 times cleaner) with lower electricity costs (10 to 20 percent lower) than is feasible with today's technology. These technologies will also increase power generation from today's average installed capacity rate of about 34 percent to 50 to 60 percent. Two major areas of investment by the Department are in innovative conversion technologies (for example, fuel cells) and fundamental combustion research, which has already helped to reduce pollution and the cost of power generation. For example, studies of ash formation, transformation, and deposition have enabled utilities to improve efficiency by lowering unburned carbon losses, and to turn fly ash into a useful byproduct instead of a waste.

—*More competitive renewable energy*. The Department will support basic technology development for solar, wind, and other renewable sources of energy that emit very little pollution. Over the next decade, the Department will develop renewable energy technologies that can compete economically with traditional sources of energy, even if those sources continue to decline in cost.

—*Knowledge for sound energy policy choices*. The Department will develop an understanding of interactions between energy use and the environment sufficient to make useful predictions regarding the consequences of various energy utilization options. Of special importance is understanding the effects of energy production on the earth's climate and atmospheric chemistry.

- **Increased energy productivity.** The Department has achieved remarkable returns on taxpayer dollars with new technologies that lower the cost of energy production and increase the efficiency of energy consumption. For a few tens of millions of dollars, the national laboratories developed energy-efficient windows, lighting controls, energy-use software, and high-efficiency oil heaters that have already lowered the energy bills of U.S. consumers and business by more than $10 billion. Similar success has occurred on the supply side, such as the polycrystalline diamond drill bit that has reduced the cost of drilling for oil by as much as $1 million per well.[15] The Department's strategy to achieve more such remarkable successes includes:

—*Certifying next generation light water reactors.* The Department is continuing its technology development work in close cooperation with the private sector to help obtain Nuclear Regulatory Commission design certification of four advanced nuclear power plants, including

[15] *Energy R&D: Shaping our Nation's Future in a Competitive World*; Final Report of the Task Force on Strategic Energy Research and Development. June 1995; Secretary of Energy Advisory Board, Department of Energy; and *Success Stories: The Energy Mission in the Marketplace*, May 1995, U.S. Department of Energy.

those applying passive safety features and modular construction. These new designs will result in nuclear plants that are safer, less expensive to build and operate, and more reliable than current plants.

—*Maintain currently operating nuclear power plants.* Working with U.S. industry, the Department will perform vital research and development needed to assure the ability of U.S. nuclear power plants to continue operating well into the next century. By developing techniques such as reactor pressure vessel annealing, the Department will assure that the 110 U.S. plants that produce 20 percent of the Nation's electric power will continue operating as long as they are safe and economic. The Department will work with other countries to improve the safety of nuclear reactors worldwide, especially that of aging Soviet-designed reactors.

—*Increase the efficiency of energy consumption*. Invest in energy-efficient building, industrial, and transportation technologies.

—*Increase the efficiency of energy production.* Keep energy costs low by developing energy supply technologies with lower costs and reduced environmental impact, including renewable energy, advanced fossil fuel and nuclear power, and, in the long term, fusion.

Role of the DOE Laboratories

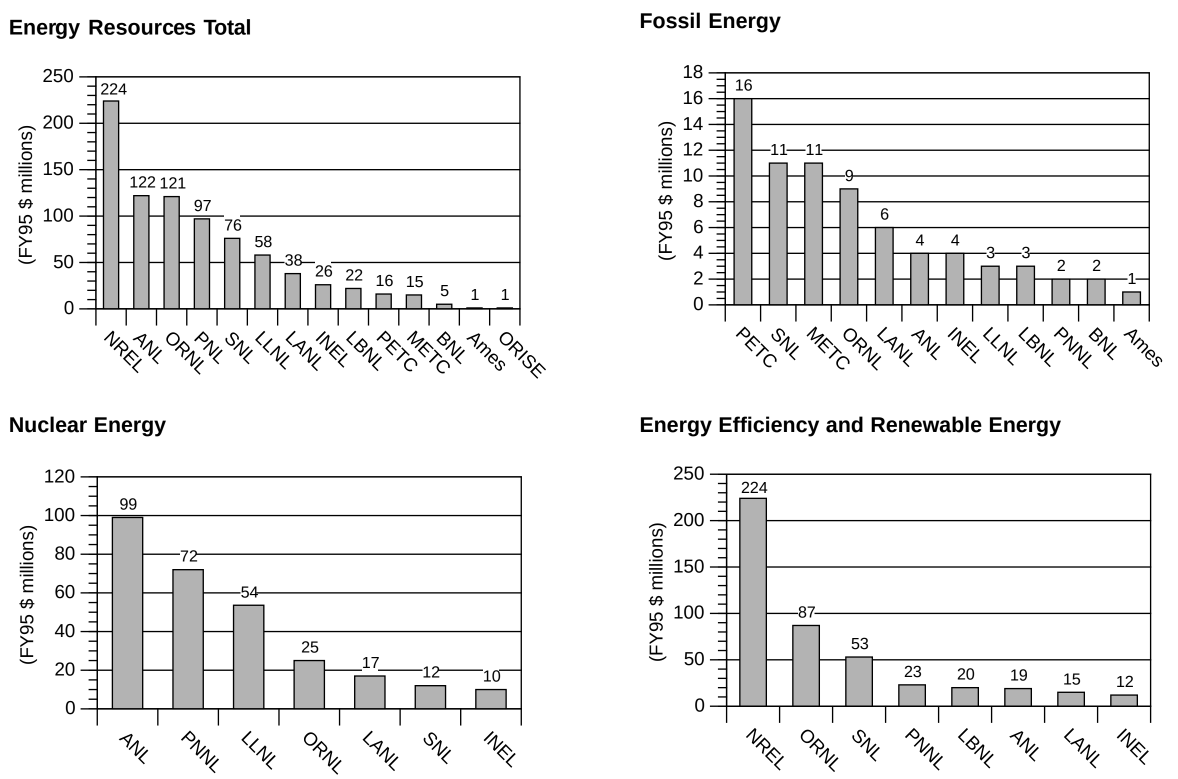
Approximately $2.47 billion (14 percent) of the Department's fiscal year 1995 budget of $17.1 billion was dedicated to the energy resources mission.[16] Of this amount, approximately $1.6 billion supported R&D activities, of which approximately $600 million (37 percent) supported energy R&D programs at the DOE laboratories. The distribution of this funding is shown in Figure 6. The balance of the R&D funds support research and technology development work in the private sector and academia.

Each of the Department's energy programs use the laboratories in different ways.

The Office of Fossil Energy uses the Pittsburgh and Morgantown Energy Technology Centers for program and project management and procurement, as well as for in-house research. The in-house research tends to be applied in nature, and focused on fossil energy-based power systems, upstream and downstream technologies and fuels. Innovative research performed at the centers has resulted in a number of advances or breakthroughs that have helped ensure the success of the FE mission. Approximately one-third of the staff at each institution performs in-house research, and two-thirds perform project

[16] This total included funding for the Strategic Petroleum Reserve, Naval Petroleum Reserves, Power Marketing Administrations, State energy grants, and numerous other non-R&D programs that are not performed at the DOE laboratories.

Figure 6. Energy Resources—DOE Laboratory Funds



Note: Fiscal year 1995 New Budget Authority (Operating)

management, procurement, and other administrative functions. On a research dollar basis, approximately 10 to 15 percent of the research budget is used to fund in-house R&D. The balance is used to fund research in partnership with industry, academia, or at the DOE multiprogram national laboratories.

The Fossil Energy program utilizes the multiprogram national laboratories both for fundamental and advanced applied research. Often a laboratory is selected because of specialized user facilities, or because core competencies sponsored by another DOE office are uniquely applicable to fossil energy problems. For example, specialized seismic sources and receivers developed for defense applications have been applied to crosswell seismic tomography to improve the discovery and recovery of natural gas and oil.

The Office of Energy Efficiency and Renewable Energy (EE) performs 80 percent of its laboratory-based R&D through the National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Sandia National Laboratories (SNL). NREL is the principle laboratory for EE and it is responsible for 50 percent of EE's laboratory-based R&D. Their unique facilities and expertise for building partnerships with program customers (industry and universities) has resulted in assignments that support all EE programs. The major programs at NREL include research in photovoltaics, biofuels for transportation, biomass power, wind energy, and building technologies.

EE programs at ORNL and SNL use expertise that has been developed at those labs to support other DOE missions. At ORNL the major programs are materials research and development for transportation technologies, the High Temperature Materials Laboratory (developed with EE sponsorship), and R&D for building technologies. SNL is the lead R&D laboratory for solar thermal technologies and has unique facilities to support this program. In addition, SNL performs R&D in photovoltaic manufacturing and geothermal technologies. Their substantial expertise in these areas was developed for the DOE national defense mission.

The Office of Nuclear Energy, Science and Technology applies the expertise at several DOE laboratories to accomplish its key missions and to augment its in-house expertise in several areas. The Pacific Northwest National Laboratory, for example, has the critical technical and managerial expertise needed to conduct Nuclear Energy's complex international activities. The Argonne National Laboratory is uniquely qualified to conduct research on electrometallurgical technology for the treatment of DOE spent fuel. The Nuclear Energy Program also applies special facilities at the Idaho National Engineering Laboratory (INEL) to continue its mission associated with the Naval Reactors program. Other INEL facilities and facilities at Oak Ridge National Laboratory are essential for the production of radioisotopes for medical, scientific, and industrial applications.

The Environmental Quality Mission[17]

National Goals

- To stabilize and safely store or dispose of nuclear waste.
- To deactivate, decontaminate, and decommission surplus facilities.
- To remediate the contaminated environment to levels acceptable for long-term monitoring or reuse depending on land use policy decisions.

[17] For the purposes of this report, the environmental quality mission primarily addresses programs to clean up contaminated nuclear weapon production sites and managing the materials and facilities associated with those sites. The Department's energy resources and science missions also provide major contributions to national environmental protection requirements.

Role of the Department

The Department manages the largest environmental stewardship program in the world with more than 140 sites and facilities in more than 30 States and territories. When the nuclear weapons production complex virtually shut down in the late 1980s, this left a legacy of thousands of contaminated areas and buildings as well as a "backlog" of volumes of wastes awaiting treatment. In addition, a large amount of special nuclear materials was left in the pipeline of production facilities. Approximately 26 metric tons of plutonium, more than 100 million gallons of high-level radioactive waste, and approximately 1,300 cubic meters of highly radioactive spent nuclear fuel are under the stewardship of the Department's Environmental Management Program.

The Baseline Environmental Management Report in 1995 predicted the life-cycle cost of the environmental management challenges resulting from nuclear weapons production to range from $200 to $350 billion over a 75-year period.[18] This estimate includes the $172 billion for dealing with the nuclear weapons complex legacy, $24 billion for future wastes for nuclear weapons facilities, and $34 billion for past and future wastes from other DOE activities.

The Department also has responsibility for the ultimate disposal of more than 84,000 tons of spent fuel from the Nation's commercial nuclear reactors. These and the high-level defense wastes mentioned above are destined for disposal in a geologic repository. The Department is currently characterizing a site at Yucca Mountain, Nevada, to determine its suitability as a geologic repository.

To accomplish the national goals listed above, the Department will:

- Assure that waste management, nuclear materials stewardship, and surveillance and maintenance of decontaminated lands and facilities are performed in a safe and environmentally sound way, thereby enabling effective management over the long term.
- Use the most effective and cost-efficient practices of industry and government, recognizing constraints on future funding commitments.
- Invest in developing the scientific knowledge base and innovative new technologies required to significantly reduce costs, meet or exceed cleanup schedules, and reduce risks to public health, workers, and the environment. These strategies will be pursued in a fashion that fosters active and open partnerships with key stakeholders.

[18] *Estimating the Cold War Mortgage: The 1995 Baseline Environmental Management Report,* U.S. Department of Energy, March 1995.

Anticipated Outcomes

Specific outcomes the Department expects to provide for the Nation by the year 2005 include:

- Safely manage the Department's plutonium, high-level radioactive waste, and highly radioactive spent nuclear fuel.
- Submit a license application by 2002 to the Nuclear Regulatory Commission for authorization to construct a geologic repository at Yucca Mountain, Nevada, if the site is found suitable.
- Reduce the risk of explosion in large, underground high-level radioactive waste tanks.
- Protect human health and the environment by advancing the science and technology needed to clean up nuclear weapons manufacturing sites. A targeted long-term basic research program for addressing environmental problems will be developed, and the necessary development, demonstration, testing, and evaluation of new generations of technologies will be completed to meet DOE needs for alternative waste remediation methods, lower life-cycle waste remediation costs, and reduce risks to workers, local populations, and the environment.
- Safely stabilize, decommission, and decontaminate more than 7,000 buildings across the former nuclear weapons complex.
- Build a foundation on the best science and technology for improved environmental stewardship and sustainable development.
- Advance environmental technologies into the next century through performance-based collaboration across technology providers.
- Aid environmental stewardship and sustainable development internationally though export promotion and partnerships with U.S.-based private sector firms that are pursuing global opportunities for environmental cleanup technology.
- Provide credible risk-based decision-making for the Environmental Management Program by developing risk assessment and management practices, with meaningful stakeholder involvement. Tools and processes for risk management will be developed, including evaluation of land use planning, acceptable risks, cost-benefit analysis, and uncertainty analysis.
- Ensure DOE laboratories are accessible for private sector, State, university, and other Federal agency partners to advance development, demonstration, and verification of environmental technology.

DOE research in pursuit of these outcomes will be leveraged through cost sharing with partners from the private sector, State, university, and other

Federal agencies to develop, demonstrate, and verify environmental technologies.

Program Management

Different offices that make up the Department's environmental quality mission employ different methods to manage their R&D activities, as described below.

The Office of Environmental Management (EM) conducts science and technology activities across a broad spectrum from targeted basic science through applied research, development, and demonstration. Program policy formulation and program development are done by EM headquarters personnel, whereas field personnel lead budget development and program implementation. Research and development performers differ across elements of the research spectrum. The EM Science Program funds research in scientific areas critical to the problems held by environmental management through targeted basic research in partnership with the Office of Energy Research. Program partners are chosen by competitive selection grounded in peer review. A Request for Application for fiscal year 1996 was issued to universities for up to $20 million. A separate request for up to $20 million was issued to the national laboratories at the same time. The remaining $10 million will be used to augment existing programs and provide a framework for the science agenda.

EM Technology Development activities are linked with DOE laboratories and production facilities and with industry and universities as research, development, and demonstration partners. Potential partners with the best skills, technologies, and ability to work at reasonable cost are selected competitively as technology developers. Laboratories perform technical management of specific focus areas or crosscutting program projects, and are competitively selected pursuant to documented peer-reviewed requirements and criteria. Industry and universities address environmental remediation needs by developing and demonstrating innovative technologies with DOE through competitively selected, peer reviewed, cost-shared partnerships. Some 40 percent of Technology Development's funding is allocated to leveraged technology partnerships with industry or universities. Small businesses are integral program participants.

For the EM Office of Waste Management, research and development funding, work scope, and selection of the performing laboratories or organizations are made at the program level within the operations offices. However, headquarters is often involved in decisions on research and development activities that (1) require a significant level of funding over a long period of time, (2) effect significant changes to program policies or strategies, or (3) impact the organization's return on investment from a waste management corporate perspective.

The Office of Civilian Radioactive Waste Management (RW) uses the prime contractor to the Yucca Mountain Site Characterization Office as its management and operating (M&O) contractor. For determining which R&D activity goes to what R&D performer, the DOE program office provides planning guidance that identifies the technical work to be done to the M&O contractor who determines the best qualified subcontractor/laboratory to perform the work. Using DOE's planning guidance, the M&O develops and submits draft Work Authorization Directives to DOE. The draft directives are negotiated with DOE and when the directives are finalized, they become the contractual agreement between DOE and the M&O contractor. The directives authorize the M&O to enter into a Memorandum Purchase Order (MPO) with the laboratories. Draft purchase orders are negotiated between the laboratories and the M&O contractor with the latter issuing finalized MPOs to the labs. Finalized MPOs are the formal agreement between the labs and the M&O contractor.

In fiscal year 1995, The RW program office delegated authority to the M&O as prime contractor to consolidate and integrate all work performed by the various contractors on the Yucca Mountain project. The M&O provides technical direction to all project contractors. Agreements are between the M&O Contractor and the laboratories; reporting is done through the M&O contractor. The RW program office approves all work done under the M&O contract.

Role of the DOE Laboratories

The national laboratories will take a leadership role in the integration of science and technology internal and external to the Department to ensure that research resources are being expended in the most cost-effective manner and to ensure that the Department's research assets can be brought to bear to achieve our environmental quality objectives. The national laboratories will demonstrate their support for the Department's Environmental Management program by being "best in class" in remediation, pollution prevention, reuse and recycle, waste management, and resolution of existing environment, safety, and health problems created by past practices and activities.

The laboratories bring two major capabilities to bear in performing research toward the environmental quality mission: (1) knowledge and understanding of the technical problems facing the Department's cleanup challenges, and (2) specialized scientific and technical capabilities. Many of the Department's laboratories confront a large range of environmental problems on their own sites, and consequently have firsthand knowledge of the problems. Through the Environmental Management Technology Systems Program, the laboratories are currently engaged in performing technical tasks to address both their own and complex-wide environmental problems; moreover, their knowledge and understanding is of national scope, and not restricted to DOE cleanup. As the Task Force on Alternative Futures for the Department of Energy National Laboratories noted, the national laboratories' own sites can "serve as test beds for the development of a broad spectrum of improved remediation, waste minimization and cleanup technologies for application on far larger scales."

The national laboratories' technical capabilities include personnel with backgrounds in scientific and technical disciplines applicable to environmental remediation R&D, as well as the necessary facilities and technical and management infrastructure. The laboratories are capable of forming the interdisciplinary teams needed to apply a life-cycle systems approach to solving remediation problems. Additional qualifications include the laboratories' established links to the scientific community, industry, local stakeholders, tribal governments, and State and Federal regulators.

Primary responsibility for different elements of the Department's environmental quality mission are assigned to different laboratories.

Idaho National Engineering Laboratory is the lead laboratory for the Mixed Waste Focus Area, which develops, demonstrates, and deploys technologies for the characterization, treatment, and disposal of waste contaminated by both hazardous and radioactive constituents.

Morgantown Energy Technology Center is the lead laboratory for the Decontamination and Decommissioning Focus Area, facilitating the proof-testing and deployment of industrial technologies for cleanup and restoration of weapons production facilities.

Pacific Northwest National Laboratory leads the laboratory effort in the Tanks Focus Area, enhancing environmental quality by developing technologies to remediate deteriorating and leaking hazardous waste within storage tanks such as at the Hanford Site.

Savannah River Technology Center is the lead laboratory for the Subsurface Contaminants Focus Area, which concentrates on cleaning up landfills, wetlands, and groundwater polluted by industrial wastes and migrating contaminants.

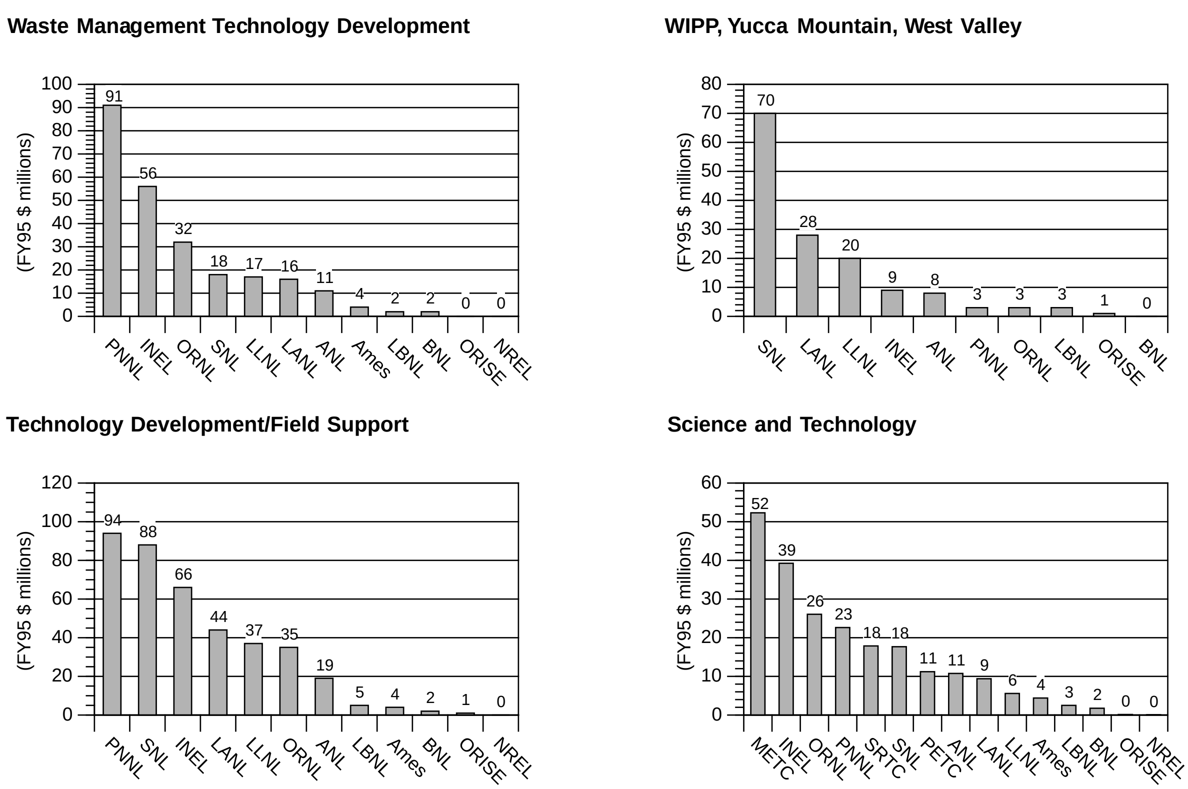
Sandia National Laboratory supports the Waste Isolation Pilot Project (WIPP), a geologic repository for transuranic waste.

Los Alamos National Laboratory is providing integral program support for plutonium research and development and implementation of the Defense Nuclear Facilities Safety Board Recommendation 94-1. A lead laboratory for these functions has not yet been identified.

Approximately $6.5 billion (38 percent) of the Department's fiscal year 1995 budget of $17.1 billion was dedicated to the environmental quality mission, including efforts to develop a long-term repository for civilian radioactive waste and to maintain environmental, safety, and health programs for the Department and its facilities. Of this budget, approximately $425 million was spent on research and technology development. Of this amount, 59 percent[19] was spent at the DOE laboratories and production facilities, with the balance supporting private sector and university R&D. The distribution of Environmental Quality funds including some activities other than R&D is shown in Figure 7.

[19] This includes activities that are funded from the Office of Science and Technology, of which 45 percent is directly at the laboratories. In addition, this figure includes approximately $100 million in technical activities at the laboratories that are funded by the Office of Waste Management.

Figure 7. Environmental Quality—DOE Laboratory Funds



Note: These values do not correlate directly with B&R Budget Authority values; they derive from EM and OCRWM budget crosscuts.

The Science Mission

National Goals

Maintain excellence in science and technology into the next century to ensure U.S. leadership across the frontiers of scientific knowledge. This mission supports all other missions of the department, and provides the foundation for future success in these areas.

Role of the Department

The Department of Energy has an essential and continuing mission in supporting U.S. leadership across the frontiers of science. The nation realizes the return from public investments in fundamental research through direct contributions to knowledge, the development of new technologies, and through the education of future scientists and engineers. Scientific inquiry is an essential link in a complex and interactive web of discovery and practical invention. Advances in mathematics, physics, chemistry, biology, and many other sciences provide the foundation for technical advances in agriculture, engineering, production, and technical applications. Advances in technologies, in turn, further advance fundamental knowledge. The Federal Government has a unique and central role in supporting this mission given the long-term nature of fundamental research.

The Department's program managers are responsible for managing its research program; they do this by setting goals for the program which are consistent with Executive and Congressional guidance, selecting appropriate research performers from laboratories or universities, and by monitoring their performance in accomplishing the research objectives. The DOE national laboratories are preferred performers for complex projects that utilize multiple scientific disciplines and require technical management competence. Universities are the performers of choice for research best carried out by a small group of investigators.

An important part of the science mission is to provide large-scale, complex scientific facilities for laboratory, academic, and industrial users throughout the country. These user facilities include experimental devices such as synchrotron light sources, neutron sources, and particle accelerators. Tens of thousands of scientists and engineers use these experimental facilities each year for fundamental research and to solve industrial problems. These sophisticated facilities are built and operated by the national laboratories because they require the management and multidisciplinary capabilities that only the Laboratories can deliver, and they are too costly for companies to provide for themselves. In building and operating such facilities, the Department provides a national resource for the country.

The science programs of the Department comprise the largest federally funded program of basic research in the physical sciences. The Department is also responsible for a large fraction of the federally funded efforts in environmental science, life science, and mathematics and computing. Over 65 Nobel prizes in physics and chemistry have been awarded to scientists whose research was supported by DOE or who used departmental facilities. Last year, the two winners of the Nobel prize for physics and two of the three persons receiving the Nobel prize for chemistry were supported by the Department. Projects supported by DOE for the science mission and other missions, have won 383 “R&D 100 Awards” over the years since their inception; these are awards granted by *R&D Magazine* for the most important technology developments in the country. DOE has been recognized with more than twice the number of any other government or private sector organization. Thirty-five of last year’s “100 Awards” went to DOE science and technology projects.

The Department of Energy is a major contributor to the science and technology enterprise of the nation. DOE national laboratories have produced a steady stream of scientific and technological discoveries that meet national needs for advancing knowledge in a myriad of fields. Their research ranges from the most basic studies of the ultimate constituents of matter to the discovery and advancement of new, breakthrough technologies–not only in the area of energy, but also in high-performance computing, biotechnology, advanced manufacturing, materials, and the environment, to name just a few. The department brings together the resources of government and the capabilities of university and industrial scientists to serve the nation’s needs. Virtually every aspect of American life–from medicine, to manufacturing, transportation, communication, energy, defense–has benefited, and in some cases been transformed, by the fundamental scientific discoveries of the DOE national laboratories in the past 50 years.

Anticipated Outcomes

The Department anticipates that investments in its science mission will generate benefits during the next 20 years that include the following:

- Forefront, leading-edge research facilities will help maintain world leadership for the United States across many fields of science. Access to these facilities will be assured for academic, industrial, and laboratory scientists and engineers.
    - —New facilities for high energy and nuclear physics research will be in operation including a “B-Factory,” an upgraded Tevatron accelerator, a continuous electron beam accelerator facility, and a relativistic heavy ion collider.

—A new neutron spallation source and a state-of-the-art intense x-ray light source will be operating to study the structure and properties of physical, chemical, and biological materials.

—International partnerships will be established for reciprocal use of U.S. and foreign facilities to ensure access for U.S. scientists to foreign facilities and to benefit from research done by other countries.

- Advances in materials and chemical processing will enable the introduction of new energy-use systems and manufacturing processes that use energy more efficiently, support the economy, and protect the environment.
- The multi disciplinary integration of a diverse set of sciences, including chemical structure and dynamics, separation science, materials and interfaces, microbial ecology, and environmental dynamics, coupled with computational science will lead to innovative and far less expensive environmental cleanup methods, and tools for minimizing manufacturing waste streams.
- Research on advanced plasma science, fusion science, and fusion technology will provide the knowledge base needed for economically and environmentally attractive fusion energy source. This research will continue to contribute to practical near-term applications, such as plasma processing, particle accelerators, and microwave generation.
- Research in combustion dynamics, catalysis, materials, photochemistry and related energy sciences, focused to improve components such as batteries, high temperature materials, lightweight materials, superconducting materials, energy storage mechanisms, and automotive engines will lead the nation to expanded and more efficient use of its domestic energy sources in a manner that is affordable and environmentally acceptable.
- Advanced computer models of global climate and quantitative data on the rates of important processes that affect climate will lead to improved global climate change predictions and provide solid technical underpinnings for policy decisions concerning mitigation strategies, regulatory actions, and adaptive measures.
- Sequencing and mapping of human and microbial genomes and advances in structural biology will help identify causes and guide the treatment of disease. The advancements also will lead to improved manufacturing processes using microbes for energy production and environmental remediation.
- Integration of biotechnology with nuclear medicine will lead to development of new techniques for applying radioisotopes to medical research, diagnosis and therapy. The Department also will provide radioisotopes and generators of radioisotopes at remote, clinical settings for medical

applications. The knowledge generated in the human genome project will be integrated with medical applications as a basis for a more healthy citizenry and, with advances in computer communications, with a wider distribution of these benefits to less populated areas of the Nation.

- Science-based stewardship of the nuclear stockpile will sustain U.S. military strength in a safe and environmentally acceptable manner.
- Through advanced computer tools and simulations, scientists and engineers will have remote, on-line access to DOE laboratories and facilities. They will be able to operate facilities and gather experimental data from thousands of miles away.

Role of the DOE Laboratories

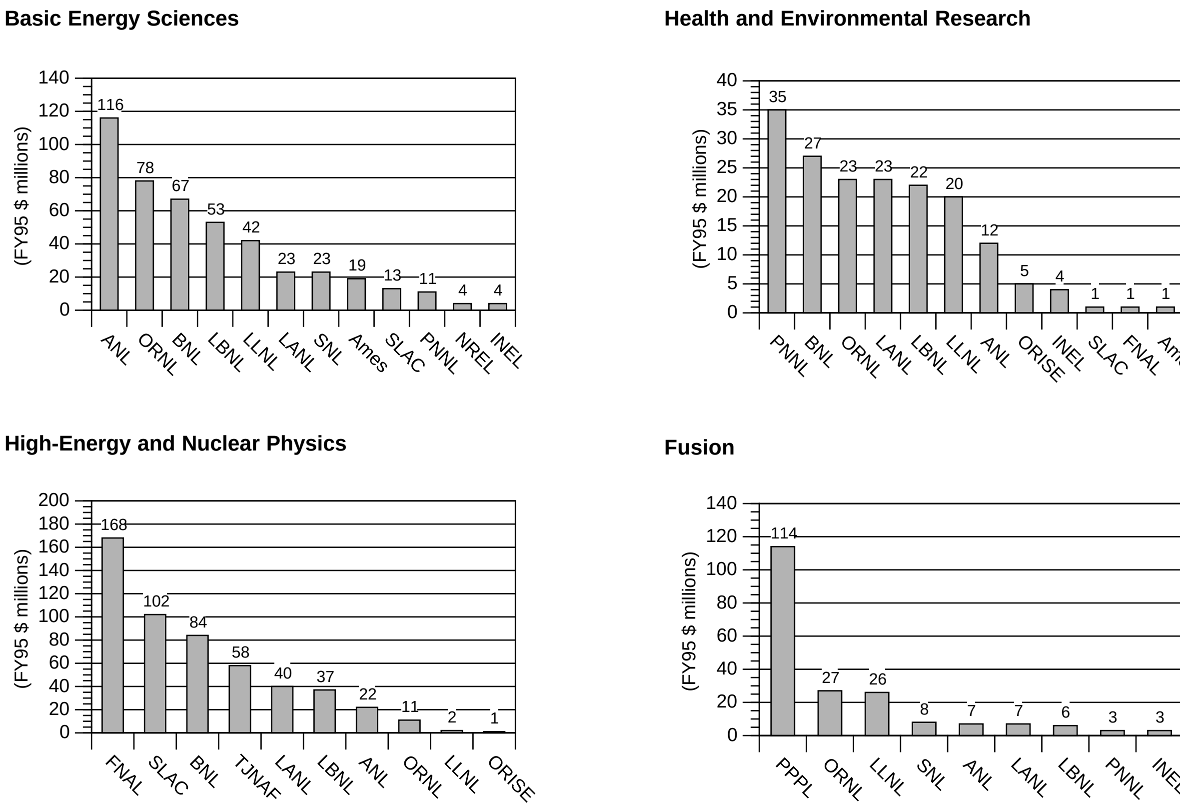
Of the Department's Fiscal Year 1995 budget of $17.1 billion, only about $2.7 billion (16 percent) was dedicated to the Science mission. The DOE national laboratories conduct the bulk of the DOE science program funded by this budget. This distribution of these funds is shown in Figure 8. The laboratories are generally recognized among the world's highest quality research producers; this is supported by their success in winning international and national awards and other measures of scientific output. The reasons for their excellence are several, but among them is the Department's use of private sector, rather than government, organizations to operate the laboratories. The contractors selected to manage the laboratories for the science mission are always institutions and organizations where science and technology are primary drivers in management decisions, and where technical merit is a most important consideration in the conduct of the work and recognition afforded to the staff.

The DOE laboratories are organized to provide mission oriented research programs. In this effort, all of the laboratories maintain a strong base of scientific capability which enables them to bring together multi disciplinary teams to solve complex scientific and technological problems.

The DOE laboratories are well positioned to formulate and carry out complex scientific programs that are in the national interest. With Federal funding, the laboratories move into new problem areas quickly; for example, rapidly putting into practice new discoveries in high-temperature superconductivity in the 1980s. National laboratories also sustain long-term programs needed to bring promising research to applications. This multi disciplinary, focused activity on problems of national importance is not easily provided by other parts of the government or the private sector.

A special role accepted by the Department of Energy is to provide large-scale, leading-edge facilities at the national laboratories for public and private research and development. The Department, through its Laboratories, is the

Figure 8. Science—DOE Laboratory Funds



Note: Fiscal year 1995 New Budget Authority (Operating)

country's major designer, builder, and operator of large research facilities (that is, particle accelerators, synchrotron radiation light sources, neutron sources, high-temperature materials and combustion laboratories, electron microscopes) that require resources of a national or international scale. All three of the major science facilities brought on line in the last three year have been completed within schedule and within budget.[20] The Department's scientific research facilities not only advance the missions of the Department, but they also contribute to national science and technology capability and excellence. Every year more than 15,000 scientists from 275 colleges and universities, nearly 50 Federal laboratories, and more than 260 private sector companies in all 50 states utilize the Department's research facilities.

[20] These include the Advanced Light Source at LBNL, the Advanced Photon Source at ANL, and the Thomas Jefferson National Accelerator Facility.

The DOE laboratories have developed strong and sustained relationships with industry and the universities for the advancement of scientific research goals. In what may become one of their most significant roles, the laboratories have functioned among the nation's most effective training grounds for the successive generations of young scientists who go on to enter government, private industry, and the academic community. The national laboratories have recruited and retained scientific and technical staffs of outstanding caliber to work on important forefront areas of scientific and technical inquiry. The enormous range of talent, creativity, and collective scientific knowledge that these scientists bring to DOE's national laboratories represents one of the great strengths of the laboratory system.

Research Programs Management at DOE

The Department conceives and manages its scientific programs in order to accomplish its science mission. The Department sets research directions and priorities, plans coherent and integrated research programs using an appropriate mix of performers, ensures that the highest quality research is funded, and coordinates its research efforts with applied research and development programs of the Department and with research performed by other agencies and by other nations.

A variety of mechanisms are used to set directions and establish priorities for research. The Department accepts Administration and Congressional guidance to help establish priorities for broad areas of research which are outlined in the Department Strategic Plan. Standing advisory committees direct attention to evolving national needs and scientific opportunities. For example, in the last three years, advice from the High Energy Physics Advisory Panel, the Fusion Energy Advisory Committee and the Nuclear Sciences Advisory Committee has led to significant changes in program direction. The Department also requests guidance from the National Academy of Sciences on specific program questions or policy. Program managers in the Department frequently use workshops to help focus research on problems relevant to the Department and to explore new directions. Often, these workshops are sponsored jointly with other Offices in the Department, industrial organizations such as the Electric Power Research Institute, and other agencies so that the needs of the technologies and interagency issues are reflected in the research programs.

Once the direction of a program is established, the primary responsibility for the structure, quality, and direction of the research rests with the Department's program managers. For the case of research best performed by individual investigators, proposals for new research are solicited by program managers and then sent to several expert scientists for review. The opinions of these scientific peers are important for program managers who make decisions for awards, generally for a three to five year period. This peer review process helps ensure that work that is supported is relevant to the Department's needs, is of high quality, and is likely to be successful. For ongoing research, program managers promote exchanges of information among research performers and organize meetings of performers and reviewers to assess progress. Individual awards are reviewed annually for satisfactory progress, and usually undergo external peer review when investigators submit another research proposal. Some program managers have selectively adopted this form of research funding, i.e., competitive proposal selection, in funding activities within the DOE laboratories.

Standing Coordination Committees for areas with department-wide interest, such as materials, combustion, and bioenergy, help ensure that basic and applied research is coordinated with the Department's technology programs, with the research of other agencies, and with research of other countries. Much of the basic research supported at the Department's laboratories is co-located with applied research activities; for example, the High Temperature Materials Laboratory is located at Oak Ridge National Laboratory, thus facilitating incorporation of the results from basic research into energy technologies. Program managers participate in interagency coordination committees and in the National Science and Technology Council. The Department's Advisory Committees and the individual Laboratory Review Committees, which have representation from universities, industry, and government laboratories, are asked to examine the relationship of the research being supported with its application areas. The research is integrated into the economy through publication of results in scientific journals, through participation in scientific meetings, and through collaborations with industry. In appropriate cases, joint programs are developed with other agencies, both to avoid duplication and to coordinate research across agency boundaries. For example, plant sciences research, high-performance computing, and global climate change research are effective joint programs. Coordination with international research efforts is accomplished through formal agreements and through international meetings and workshops.

To improve the management of the science mission, the Department does plan to use the newly reestablished R&D Council to assure the increased integration of DOE research and technology programs. Furthermore, programs will be reviewed to ensure that an appropriate mix of performers in laboratories, universities and industry is being used to carry out the program effectively and efficiently.

Representative Research Programs and Program Management

The following examples illustrate how DOE conducts its science mission and uses its laboratories. The different management approaches in these examples arise from the differing nature of the research topics.

High Energy and Nuclear Physics Research. This program investigates the ultimate constituents and structure of nuclei and subnuclear matter and the fundamental forces of nature. Much of this $1-billion per year program of research depends upon unique, major accelerator facilities at Fermilab, the Stanford Linear Accelerator Center, the Thomas Jefferson National Accelerator Facility, Brookhaven National Laboratory, Argonne National Laboratory, Oak Ridge National Laboratory, and the Lawrence Berkeley National Laboratory. The facilities are distinct from each other in their features and performance, differing in the research that can be done and the results that are achieved; all contribute separately to advances of these fields. Support is directly provided to many of the 4,000 laboratory and university users of the facilities. In addition to the research performed by the program, broad industrial and medical applications and other spin-offs often arise out of the unique state-of-the-art technology which is developed for this program.

Because the program is strongly dependent on the large accelerator facilities, the DOE program managers work closely with the laboratories to coordinate the research and facility operations. Formal Users Groups at each of the user facilities provide valuable information about needs and opportunities to optimize their programs. Advice on strategic planning and scientific priorities is provided to DOE senior managers and to Laboratory Directors by the High Energy Physics Advisory Panel and the Nuclear Science Advisory Committee. These formal advisory committees consist of members that broadly represent the disciplines. The advice from both committees is also provided to the National Science Foundation, which provides about 10 percent of the funding in these scientific fields.

DOE managers also obtain valuable information for management of the program from extensive peer reviews conducted with scientific experts, from scientific conferences where results and emerging opportunities are discussed, and from technical organizations such as the American Physical Society. Managers also utilize individual professional interactions with scientists throughout the world, informal meetings, and the distribution of written reports.

Research Enabled by Synchrotron and Neutron User Facilities. Synchrotron light sources are large and complex facilities used to probe the electronic structure of atoms and molecules. The electromagnetic radiation provided by different light sources (ultraviolet, soft x-rays, hard x-rays) probe the structures, molecular bonds, and dynamics of materials that are important in biology, medicine, chemistry, environmental science, agricultural science, and geology. Neutron sources penetrate more deeply into materials and interact more directly with atoms and molecules than electrons. Measurements with neutrons give precise information about the positions and motions of individual atoms in the interior of a sample.

Four synchrotron facilities and four neutron sources are operated at DOE laboratories. These state-of-the-art facilities are used each year by thousands of industrial, academic, and government researchers. They are, in fact, greatly oversubscribed in that thousands of additional users cannot be accommodated because of the limited experimental time that is available The facilities serve different purposes and different groups of users. The Advanced Light Source at the Lawrence Berkeley National Laboratory, for example, provides visible, ultraviolet, and soft x-ray radiation for studies of the electronic properties of micro structures, surfaces, ultrathin layers, and x-ray lithography. The Advanced Photon Source at the Argonne National Laboratory, on the other hand, provides more energetic hard x-rays suitable for gathering data at a high rate and with more detail. The facility is ideal for studies of the structure and properties of materials, smaller samples, more-complex systems, and faster reactions.

Management of this program includes facilities operation management and management of individual investigators and research teams that use the facilities and perform the research. Since experimental facilities are very limited, experiments are approved by user committees at the laboratory where the facility is located and by the investigator’s funding agencies. Approval is based on program relevance, scientific quality and importance, time and space requirements, and equipment requirements and availability to the investigator of funding. The co-location of advanced research facilities, expert staff scientists and engineers, and visiting users from a wide variety of scientific disciplines provides the nation with an invaluable asset.

Computer Research. As part of its ongoing computer research program, DOE supports advanced research in computer simulation to examine the solution of problems not easily amenable to experimental investigation. DOE also supports a computer network, ESnet, that allows worldwide access to DOE facilities, enabling scientists at different institutions real-time communication with each other and with off-site experimental facilities. Research groups from different DOE laboratories can now effectively work together without being co-located, thus enabling the start of a “virtual laboratory” system.

In fiscal year 1992, the office of Energy Research initiated nine Grand Challenge projects crucial to energy issues as a part of its participation in the U.S. High Performance Computing and Communications (HPCC) initiative. All projects are co-funded with industrial partners or other agencies. Participants include DOE laboratories, universities, industry and other HPCC agencies.

Projects address the Grand Challenges through the development of advanced computer algorithms and software, usually for parallel processing computers.

The selection of projects is made by a panel including DOE program managers and other HPCC agency participants. Each project undergoes periodic reviews to assess research progress and future plans for continued funding. Current projects are in computational chemistry, computational structural biology, mathematical combustion modeling, quantum high energy and particle physics, oil reservoir modeling, numerical modeling of fusion energy reactors, global climate modeling, development of a computer program for ground water transport and remediation, and simulation of materials properties.

Other Research Programs. A comprehensive *combustion research* program at the national laboratories has been structured by DOE program managers. Combustion accounts for 90 percent of the energy generated and used in the U.S. and it is likely to remain dominant for the coming decades. Achieving energy conservation while minimizing unwanted emissions from combustion processes would be greatly accelerated by accurate quantitative predictions of combustion performance.

The Combustion Research Facility at Sandia National Laboratories, Livermore, California, is a major experimental user facility for providing data and experimental confirmation of predictions. The laboratories that use the combustion facility each bring a particular capability to the research program. Understanding reaction rates and means for calculating their values is a strength of research at the Argonne National Laboratory. The Brookhaven National Laboratory concentrates on spectroscopy and energy transfer to determine energy flow at a molecular level. Methods for reducing the computational complexity of combustion computer models has begun at Sandia. The experimental programs at all the laboratories complement the ongoing theoretical development.

The *Human Genome Project* stems from DOE’s need to examine the genetic consequences of exposures to energy-related materials and from capabilities in DOE laboratories. The program is a collaborative effort with the National Institutes of Health (NIH) and with international programs to analyze, at the molecular level, the entire human genome over the next 10 years. The DOE laboratories bring to this program the state-of-the-art scientific, engineering, and computational tools that make the project feasible. DOE, in 1986, was the first agency to propose and commit to this goal.

The DOE and NIH coordinate through joint planning meetings, frequent staff interactions, and joint funding of key projects. The program takes advantage of the unique capabilities and resources offered by each agency. The DOE program component focuses on the use and development of advanced, cost effective, and highly automated technologies for physical mapping, sequencing, and informatics. The NIH program focuses on genetic mapping, the identification and characterization of disease genes, the genomes of model organisms, and sequencing technology.

The DOE program funds research at eight of the national laboratories, more than 40 universities, and several companies and nonprofit institutions. Three of the national laboratories, Los Alamos, Lawrence Livermore, and Lawrence Berkeley National Laboratories, have designated genome centers. The quality, focus, and balance of research in the DOE genome program are maintained through a combination of directed calls for new peer-reviewed research and the regular peer review of ongoing research.

The *Natural and Accelerated Bioremediation Research* program will provide scientific understanding needed to harness natural processes and to accelerate these processes for the bioremediation of contaminated soils, sediments, and ground water at DOE facilities. The program is new and will focus on *in situ* bioremediation of complex mixtures of contaminants present at DOE facilities. Scientific understanding will be gained from both laboratory and field research.

Field research centers and the supporting infrastructure will be established to facilitate long-term, interdisciplinary research. Computational models will be developed as integrating tools, as well as to provide methods for predicting and optimizing the effectiveness of bioremediation. Interdisciplinary research teams will be developed and a new generation of scientists and engineers will be trained to address interdisciplinary problems related to biogeochemical processes. The Department will also establish effective partnerships to address societal issues and concerns and to use and share the knowledge acquired from the program.

The *Atmospheric Radiation Measurements* program (ARM) provides data to improve the performance of computer models for predicting global and regional climate change. The major emphasis of this work is on the critical contributions of atmospheric radiative processes and the effects of clouds on climate change. DOE laboratories provide much of the equipment and long-term management at the highly instrumented measurement sites. University and laboratory scientists take data and analyze the information.

Applications for research are solicited annually and awarded competitively. The competition is unrestricted. All projects are peer reviewed and awards are based on scientific merit and program relevance. The initial ARM program plan and major subsequent program documents have been peer reviewed. The program as a whole is reviewed at least annually by a Technical Oversight Group. Major programmatic decisions are also reviewed by an Executive Committee and coordinated with counterparts in other Federal agencies. The program sponsors various scientific working group meetings throughout the year as well as an annual Science Team Meeting.

The ARM program is closely linked with global change counterparts in other agencies, particularly NASA, NOAA, and NSF. An ARM site in the Southern Great Plains has drawn collaborations from national and international programs, including the Global Energy and Water Experiment. Numerous The Tropical Western Pacific ARM site is attracting collaborations with Australia, Papua New Guinea, and Japan. The North Slope of Alaska site is closely coupled with both a NASA Regional Experiment Program and an NSF Ocean Program. The ARM data system is a part of the interagency Global Change Data and Information System.

The Economic Productivity Outcomes of Primary DOE Missions

National Goal

To make the Department's mission-oriented R&D provide the maximum benefits to the Nation through effective linkages with the private sector.

Role of the Department

The Department is committed to maximizing the value of the public investment in the national security, energy, environmental quality, and science missions of the Department by getting innovations that emerge from these investments to the marketplace. In many cases, the successful execution of the Department's core missions depends upon partnerships with the private sector. As recommended by the Task Force on Alternative Futures for the Department of Energy National Laboratories (Galvin Task Force), these partnerships are "focused on industries and areas of technology that contribute directly to the DOE's primary missions in national security, energy, and environment."

Anticipated Outcomes

Some of the anticipated outcomes from this work include:

- The Department's defense work will lead to advances in commercial technology in computing and software, materials, and manufacturing. For example, it has stimulated the development of the first trillion operation per second computers.
- Energy efficiency technologies will reduce the energy costs of industrial sectors, improving their productivity and competitiveness. Energy supply and generation technologies will lower the costs of energy to the

economy, aiding economic growth, and will lead to a more internationally competitive U.S. energy industry.

- The environmental technologies that the Department develops for its own needs will help other agencies and the private sector reduce waste and more efficiently cleanup waste sites. The technologies also will help the U.S. environmental industry export technologies and services abroad.
- The Department produces and distributes isotope as an outcome from its nuclear reactor program. Radioisotopes and stable isotopes are used in nuclear medicine, scientific research, and industrial applications.
- Basic science work will create new fundamental knowledge that will spark innovation, and will spur the development of new technologies, such as the accelerators and detectors that have contributed to medical technology. The Department's scientific user facilities, such as light sources and neutron sources, will be used by companies to develop new technologies and products that contribute to economic growth.

Many of these outcomes have been described in more detail in the previous sections.

Role of the Laboratories

A significant portion of the laboratories' work is leveraged with private sector R&D. In the last 5 years, the Department has entered into more than 1,500 cooperative R&D agreements (CRADAs) that leverage laboratory R&D with private sector R&D. The cumulative value of these partnerships is approaching $3 billion. The laboratories also license technologies to the private sector, operate scientific facilities that are used by approximately 260 companies, and perform work for companies on a reimbursable basis (termed "work for others").

The economic productivity activities involve all of the Department's laboratories, because the primary missions from which they are derived encompass the activities of all of the laboratories.

VIII. Laboratory Mission Profiles

Each of the Department's laboratories has a distinctive set of capabilities and resources that are used to advance the Department's mission objectives. This section provides concise profiles for each of the Department's 22 laboratories. Excluded from this group of laboratories are several small facilities that currently are being reviewed for possible management changes, including privatization.

To get a true picture of the value and diversity of the DOE laboratories, there is no substitute to visiting these institutions and witnessing the R&D currently under way across the spectrum of the Department's missions. However, the following profiles provide a summary depiction of the major facilities, key research and development activities, funding history, relationship to the Department's missions, and key collaborations with other R&D performers for each of the Department's laboratories. More detailed information on each of these laboratories, and on the major facilities and programs supported therein are contained in the Institutional Plans for each laboratory, which are available from the Department.

Several elements of the profiles require some explanation.

The budget listed in the **Laboratory Information Box** is the total budget for the laboratory, including work sponsored by other organizations, "Work-for-Others" (WFO). As a result, this figure is larger than the total amount of DOE funding for the laboratory.

The amounts reflected in the **Funding History** box also is the total budget for each laboratory. Note that these include activities, such as work for others, waste cleanup and environment, safety and health activities, that are not included in the mission activity profiles in volume II, which include only research and technology development activities. The sum the laboratory activities represented in volume II will be less than the budget represented here in the laboratory profile.

The **DOE Mission Footprint** reflects the percentages of a laboratory budget dedicated to R&D in the four DOE missions: national security, energy resources, environmental quality, and science. Although science is conducted in each of the missions, the figures here refer to funding through the Office of Energy Research. In general, Work-for-Others is not included because the focus is on DOE mission R&D. Two exceptions were made, however, for Lawrence Livermore National Laboratory and Pacific Northwest National Laboratory because much of their Work-for-Others is research directly tied to the Department's missions and is supported by a DOE contractor or affiliated corporation.